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A SUMMARY OF THE SALIENT FEATURES OF THE

GEOLOGY OF THE OREGON CASCADES

WITH SOME CORRELATIONS BETWEEN THE GEOLOGY OF THE EAST COAST OF ASIA AND THAT OF THE WEST COAST OF AMERICA

By
Warren Du Pre Smith, Ph. D.
Professor of Geology,
University of Oregon

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INTRODUCTION

This bulletin is primarily intended to furnish a general summary of the stratigraphy of the Oregon Cascades, and second, to draw attention to some of the salient features of the geology of the Pacific region, on both the American and Asiatic sides.

Some fifteen years ago the writer began the study, on the ground, of Philippine geology. During the course of this work he made trips to Japan, Borneo, the Malay peninsula and the Chinese coast, and perused a large number of books, reports and papers pertaining to their geology. Three years ago he came to Oregon, having spent two years in California some time before. The larger aspects of this paper were suggested to him years ago by the following paragraph in a letter received from Dr. Bailey Willis:

> Although the Pacific lies between, and seems to separate you from the more familiar phases of the geology of North America, I am of the opinion that, geologically, you are more in touch with our western coast than the man who is studying the geology of the eastern United States. The ocean basins are the sources of the great dynamic effects which characterize the continental margins, and there is more likeness between the opposing shores of the Pacific than there is between the opposite sides of the continents. I have been interested, in the course of my work, to find that the geology of California is the geology of central China, and that there is a close likeness, even in the character and date of mineral deposits, between our western cordillera and the East Indies. These similarities in geologic history, in orogeny, in vulcanism, and even in mineralization, are too close, and too long continued, to be fortuitous. We shall reach an understanding best by regarding the ocean as the center, and the continental region as the periphery, and by recognizing that the major phenomena differ when we cross the periphery from the sphere of activity of one ocean to that of another.*

In the summer of 1915 the writer of this paper spent seven weeks in the field for the Oregon Bureau of Mines and Geology, investigating certain phases of the stratigraphy of the Oregon Cascades, from Douglas county to the Columbia river. This was supplemented by trips in the summer of 1916 to Crater lake, by way of the Rogue river, and to the Three Sisters region; both on the summit of the range. In the summer of 1917 he spent five weeks in the John Day valley east of the Cascade mountains.

The shortness of funds for this sort of work, fortunately, did not permit the undigested results of the early field work being published by the bureau, and so, permission of the director has been obtained to use the results of the investigations made at that time, which have been added to by subsequent research in the field, and the literature already published. Cascade stratigraphy has been extensively written about, but the various articles are scattered through many publications, and extend over a long period. Two men, Diller and Washburne, have contributed perhaps more than any others to this subject.

The writer's only excuse for publishing, at this time, what must be an incomplete summary, is that he has wanted just this sort of thing for his own use, and, therefore, ventures to assume that other workers may find it suggestive and useful. It is planned to pursue this investigation further by more intensive faunal studies on the part of the department of geology.

Grateful acknowledgments are hereby made to Prof. James Perrin Smith of Leland Stanford, Jr., University, who has helped the writer

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* The reader is referred also to B. Willis, Research in China, Vol. II, p. 125.

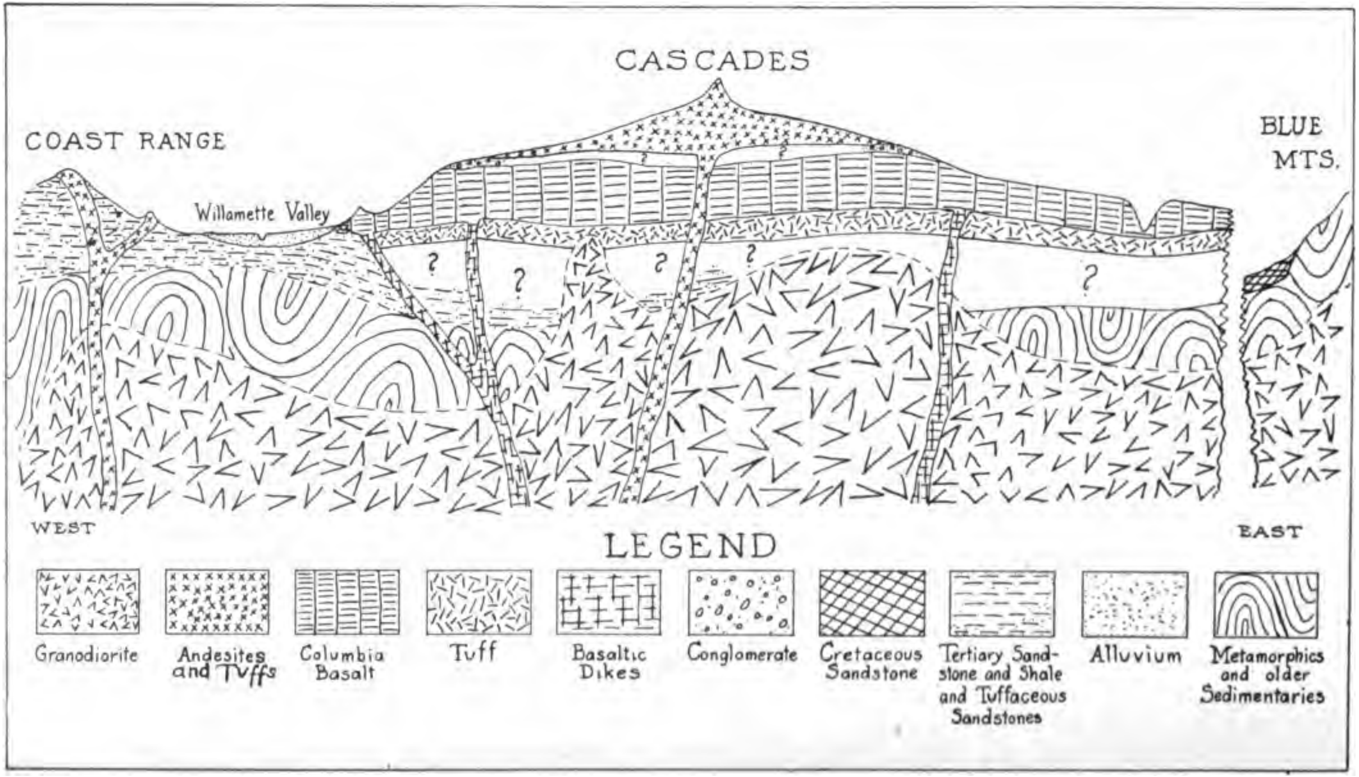

Fig. 1.—Idealized Section of the Cascade Range.

considerably with the bibliography; to his colleague, Dr. Earl L. Packard, for his helpful comments and for paleontologic data; and to Prof. A. R. Sweetser, also of Oregon, for help in the determination of some of the fossil leaves. Dr. Laura Hatch, of Smith College, has also made valuable comments on the manuscript, which the writer greatly appreciates. The photomicrographs (Plate I) were made in the laboratory of the United States Geological Survey, through the courtesy of Dr. Diller.

Field Work and Method

Equipped with county and road maps, topographic sheets (where available), and oftentimes with forest maps only, with compass, geological pick, aneroid and hand lens, about all one can conveniently carry on a horse, the writer traversed as many of the larger rivers and smaller streams as he found time for. No attempt was made to carry on a real mapping. The general relationship of the several formations was the principal feature sought, and no extra time was taken to make exact measurements.

However much as we may wish to avoid offering excuses for things left undone, we may be permitted, in justice to ourselves, to mention a few of the inevitable difficulties encountered in the course of these studies. As some of these are such as we can not very well control, we have to make allowance for them and do the best we can.

The chief of these is the comparatively excessive vegetation everywhere in western Oregon, except in the flat plain of the Willamette valley. This heavy undergrowth of grass and ferns and small trees, and the forests for which our state is famous, render it often extremely difficult to find continuous outcrops and sections. This is accentuated often by the heavy accumulation of talus, and to these two natural blankets, we might add a third, which is very effective in concealing the underlying sedimentary formations, namely, the vast piles of lavas, which make up the most conspicuous part of the whole Cascade superstructure.

A fourth difficulty is the lack of accurate topographic maps. Finally, we must repeat that the factor of time is one with which geologists deal most liberally, and which they need most in their work. It oftentimes requires much tedious physical labor to unravel even a small point in geology, and still more time for the proper amount of study of the data after they have been obtained.

In order definitely and finally to unravel our somewhat tangled stratigraphy in Oregon, it will be necessary to traverse some of our rivers transverse to the Cascade and Coast ranges, with transit and stadia, and then follow this up with a minute, foot-by-foot examination of the rocks and all they contain. Hasty reconnaissance with aneroid will never accomplish what needs to be done in this field. Laborious faunal studies of each accurately located horizon must follow the field work, and comparisons with material from neighboring states must be included.

GEOLOGY OF THE CASCADES

Before proceeding with the reading of the text, the reader should consult the generalized section of the Cascades as shown in Fig. I, in order that an outline of the whole scheme may be had before launching into the necessary details which follow. Some details of structure, particularly the bowing up and minor undulations in the Columbia river, are not shown in this idealized section. For these the reader is referred to the excellent cross-section of the Columbia gorge, made by Williams.*

General Statement

To one riding up out of the Willamette plain, with his face toward the east, there appear, first, rolling hills, then more rugged hills made up of great stacks of basalt columns, and, finally, long stretches of recent lava, and in some places miles of ash and tuff, and beyond these, massive white peaks, outstanding lonely sentinels in the midst of the primeval forest, wastes of once molten rock, and about it all, an apparently age-long calm.

Our traveler then sees the great superstructure of the Cascade range, but little does he know (and for this he is not to blame) of the underlying rocks, the foundation of the great rock pile. Therefore, we shall begin with an examination of the "roots of the mountains," and from them build up our geological column layer by layer.

The general sequence of formations, beginning at the bottom, is as follows: basement complex, the older sedimentaries, metamorphics, the younger sedimentaries, the older volcanics, the younger volcanics, recent gravels and alluvium.

THE BASEMENT COMPLEX

In the Sierras and Siskiyous to the south, as is well known, are great masses of granite, or granodiorites, making what we technically term bathyliths. These granites form the core, and, in places, the entire mass of those ranges. In the state of Washington, also, there is a great amount of granite in the Cascade region, as any one can see during a railway trip across the state from west to east. In central and northern Oregon, however, we look almost in vain for a rock similar to this southern granite. If we continue the search long enough, however, we do find outcrops of crystalline rocks. In the Oregon Cascades region there are several of these, probably, but there are only two or three to which our attention has been called. One of these is the granodiorite, reported from the Quartzville mining district, which is located in Lincoln county. Mr. H. M. Parks, director, Bureau of Mines and Geology, found this sort of granitic rock on the branch of the Santiam below Quartzville, and again on the Little North Fork of the Santiam, some twelve or fifteen miles northeast of Gates.

The second locality was found during the course of our own investigation in the summer of 1915, and is located on the McKenzie river, near Silver creek. The granite (field name) can be seen along the main road for more than a mile, and extending up the mountainside as a large mass. Its exact relation to the other rocks was not determined, but it appears to be in the nature of an immense dike cutting another crystalline rock, greenish colored and finer grained in this case, which we would call diorite.

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*Williams, Ira. "The Columbia Gorge—Its Geological History," etc. Oregon Bureau of Mines and Geology, Vol. 2, No. 3.

Just what the extent of this diorite and granite is, we are not yet able to say, but we surmise that detailed examination of the deeper canyons of the whole Cascade region would bring to light much interesting data, and show conclusively that there is, in reality, a great area of this type of rock exposed.

A more exact petrographic determination, as a result of microscopic examination, is as follows:

No. 41. This is a coarse-grained, pinkish granite—or, perhaps, it would better be called a **granodiorite**—and is decidedly holocrystalline in contrast to the usual rocks in the neighborhood. The constituent principal minerals are quartz, orthoclase, some plagioclase and hornblende.

We know, from Lawson's investigations,* that similar phases of the Sierra granite occur in California, though the main mass of the Sierra bathylith is biotite-granite and not granodiorite. In his paper on the Kern river region he also speaks of small dikes of black, fine-grained lamprophyre. We have noted a somewhat similar rock on the McKenzie, associated with the granodiorite, but were never able to tell whether the granodiorite cut the darker rock, or vice versa.

On the borders of this granodiorite and "greenstone" mass, we found what resembled a conglomeratic patch of rock, but were unable to satisfy ourselves that it was a true conglomerate.

Recent work by Williams in the Columbia gorge,† has revealed a "diorite porphyry intrusive" near Shell Rock mountain, but from his description this seems to be a more basic rock than the McKenzie occurrence, and also much younger.

Topography—Form of Outcrop

One locality, naturally, is not sufficient for a basis for judgment, nevertheless, we can state that in that part of the mountains where we found these rocks exposed, the valleys are comparatively narrow, with rugged sides, and these covered with great talus slopes. In places there are rapids in the streams, but these are not unusual, for they are also common in the region of the lavas. As these crystalline rocks are more resistant, due to hardness and toughness (a matter primarily of texture), we find them "standing up," in contrast to the softer sandstones and shales, but not with as abrupt slopes as is apt to be the case in some of the basalt areas. It is also a characteristic feature of granitic rocks to have, or tend to have, rounded forms.

Economic

This rock finds a local use on the roads of the McKenzie valley, but it is a question whether it is at all suitable for this purpose, proper tests not having been made. As the traffic on the McKenzie road is considerable in the summer months, it will be subjected to a severe practical test.

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* Lawson, A. C., Univ. of Cal. Bulls., Vol. 3, p. 295.

†Williams, Ira, loc. cit. p. 98.

With careful selection, some of this stone might find a limited market as a building stone. On fresh surfaces the stone has a pinkish cast, tinged, here and there, with green (due to ferromagnesian minerals), but its use will probably be limited, owing to transportation difficulties and lack of a market.

In one example, at the border between the pinkish and darker green portions (contact between the granodiorite and the diorite), there are some dark bluish-gray splotches, indicating some metal, but in too small a quantity to enable a satisfactory determination to be made.

As the borders of crystalline masses like this are favorable places, in many cases, for the segregation of valuable metals, it might prove profitable, at some time, to prospect this region more carefully. Many ore deposits in southern and eastern Oregon are associated with granodiorite.

Crystalline Rocks in the Asiatic Region

Associated with, perhaps cutting, the metamorphics of Luzon (Philippines), both in the northwestern and southeastern portions, are more or less noteworthy masses of granitic rocks. These may represent post-Jurassic intrusions, and, therefore, be synchronous with the granitic rocks of the Cascades of Oregon.

In Korea there is a granitoid mass, which Koto* has described, and which, he says, is found intruding the "phyllitic series." The phyllitic series, he assigns, provisionally, to the Mesozoic. It should be noted, however, that a part of the Philippine granitic series, as well as that in Korea, is leucocratic (light), and not melanocratic (dark); so we must not push our correlations too far. The petrographic aspects of the granitic rocks in the Pacific region show some similarities, but considerable differences as well.

The basement rock proper in the Philippines is diorite; in some places there is a quartz-diorite facies. We have not seen a typical diorite in the Cascade region. In the Coast range of California, however, Lawson describes a quartz-diorite, the so-called "Montara granite."† This is called pre-Franciscan, i. e., older than the Mesozoic. In both regions, the American and the Asiatic, ore deposits, gold, silver and copper, principally, are associated with bathyliths of granite and diorite, indicating that there is much in common in the metallogeny of the countries bordering the Pacific. As this subject alone would furnish material for a long and separate treatment, we shall be satisfied, for the present, with merely calling attention to it.

THE OLDER SEDIMENTARIES

Though we are not yet sure of the stratigraphic position of the granodiorite, we are assuming, for the present, that it is somewhere near the bottom of our column, and that there is a hiatus between it and the formations, which we call, for convenience, the **older sedimentaries.** We must bear in mind, too, that this granodiorite is in the nature of a huge dike, in some places, and, hence, is younger than the surrounding formations.

It has been shown by Diller of the United States Geological Survey, and by Winchell for the Bureau of Mines and Geology,‡ that there is a complex of undifferentiated rocks in the Siskiyous and in the southern Cascades. These are partly Paleozoic and partly Mesozoic. It is only with the latter group of rocks, Triassic, Jurassic and Cretaceous, that we need to concern ourselves now, for the older group has not yet come within our view in the Cascades proper.

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* Koto, B. "Journeys Through Korea," p. 162.

†San Francisco Folio, U. S. G. S., No. 193.

‡Ore. Bureau Mines & Geology, Vol. I, No. 5.

Near Peel, Oregon, about twenty-one miles east of Roseburg, there is a most interesting geological section, which has been fully treated in Diller's Roseburg Folio.* In this section, some of the older as well as younger sediments, and, also, some of the metamorphic rocks associated with the former, can be seen and studied. Fortunately, the writer, during his field work, was able to obtain additional light on the structure and relationships of these rocks, owing to the fact that the district roadbuilders had opened up this formation in excavating for suitable road material.

First, we give Diller's description of this locality (where the older sedimentaries are exposed). He says:

> A remarkable feature of the chert is its banding, due to alternating sheets of different colors. The banding is occasionally conspicuous, the layers ranging from a small part of an inch to several inches in thickness. At other places the chert is massive, and the colors are irregularly intermingled, so as to give a mottled effect. It is permeated by a multitude of small veins of quartz, with a few of calcite. The veins are generally so small as to be scarcely visible to the naked eye. Seventeen small areas of this chert are noted on the map. There are probably a number of others which were not seen. With the exception of two masses near Peel, and one at the head of Buckhorn creek, they occur near the southwest corner of the quadrangle. They are associated chiefly with the myrtle formation and the metagabbro, but are also found inclosed in serpentine. The masses are usually lenticular in form, and their small size is so common a feature as to suggest that they originated in very local conditions. This peculiarity, however, may be due, at least in part, to the intrusion of igneous rocks, and also to the overlapping of later formations. * * *
>
> The age of the chert, in any particular case, is a matter of much doubt, notwithstanding the large number of radiolarian fossils it may contain. Such fossils are rarely of special value as indicators of geological age, except in a broad sense. The ones examined by Prof. Hinde, in chert from Buriburi ridge, near San Francisco, and illustrated in Mr. Ransome's paper on "The Geology of Angel Island," were regarded as Jurassic or Cretaceous. Some of the radiolaria found in the Roseburg chert appear to be identical with those in the chert noted above.

It will be noted that Diller was unable to make out, very clearly, the structure of these older beds, at the time of his work there years ago. The writer found the same old outcrops upon Mr. Lafe Engle's place, and was able to make out very clearly, in the new excavations, the bedding planes, which showed that the formation had been tilted at a high angle, more or less variable, but approximately vertical. The strike at this point is N. 80° E. The rock is reddish, through chocolate, to almost a black, and is inclined to have a slaty structure. It possesses two or more well-defined joints, resembling cleats in coal, so that it breaks up into small blocks with rather square edges. It is extremely hard and brittle, and yet, in spite of this, apparently makes a very serviceable road metal, for the ferruginous character of the rock makes it suitable for this purpose, the iron acting as a cement. The outcrops of this rock are completely surrounded by hornblende schist.

Though we could not find any contact between these sediments and the younger beds, we can easily infer, from the attitude of the

---

*Diller, S. J., Roseburg Folio No. 49, U. S. G. S.

formations, that there is a great unconformity here, which may represent a very long time interval. Certainly the physical dissimilarity is great.

A photomicrograph of this chert is shown on Plate I. Three genera of radiolaria can be made out in these slides, as follows: Cenosphaera, Dictyomitra and Spongodiscus. In most cases, only small, round areas, filled with cryptocrystalline silica, showed where the tests had been. Louderback* mentions these cherts in his "Mesozoic of Southwestern Oregon," but throws no new light on them. When the writer published, in 1916, a short note on these cherts,† he did not cite (not necessary in short notes) all the literature on this subject. He was aware, of course, that similar cherts in the Franciscan series of California had been described in detail by Lawson,‡ but with no figures of radiolaria given. On the other hand, the writer had overlooked the appendix by Hinde on the same rocks of San Francisco peninsula, published in connection with Ransome's paper on the "Geology of Angel Island." Hinde|| figures almost identical forms of Dictyomitra and Cenospraera with those seen by the writer in sections of the Oregon chert.

Identical forms, as the writer has elsewhere indicated, have been found by the writer in material lithologically similar, and in about the same stratigraphic position in the Philippine islands. Not only there do we find cherts with similar radiolarian tests, but in Borneo, Java, the Molluccas and Ceram as well. Both K. Martin and Hinde have assigned these cherts to the Triassic or Jurassic, and, following them, the writer has done the same in the Philippines. It has been suggested by some that the California cherts and those of Oregon, as well, may be Devonian in age. At the same time, we are well aware that radiolaria are far from being satisfactory index fossils.**

This is the only locality (Peel) in Oregon where the writer has seen this old chert with just this petrographic character, but in Cow Creek canyon there is a somewhat similar formation of hard cherty material, which, in places, is reported to contain fossil plants, which have been identified as Jurassic by Ward and Fontaine. The writer's search for this fossiliferous locality was unsuccessful. As the locality has been very fully described by Diller,†† we can refer the reader to his report, from which the following is an extract:

> On Cow creek, by the Southern Pacific railroad, near the whistling post, half a mile north of Nichols station, several small, but important outcrops of the plant beds occur. They are completely surrounded by Eocene and have been laid bare by its erosion. The plant beds are fine, dark, shaly sandstone, or sandy shale, much squeezed and checked, but without alteration or quartz veining. There are some calcareous nodules, and spheroidal weathering is frequent. Beds of fine conglomerate, two to five feet thick, are occasionally interbedded with the sandy shale, and the entire mass, about two hundred feet in thickness, dips to the southeast at an angle of about sixty degrees. * * *
>
> From the plant beds of the Nichols region forty-five forms are described. These two (Buck mountain) are the type localities of Ward and Fontaine, and have thus far afforded a flora of seventy-seven forms, referred to as the Jurassic flora of Douglas county, Oregon.

---

* Louderback, Journal of Geology, XIII, p. 524.

† Am. Jr. Sci., Vol. XLII, Art. XXXIII, p. 299.

‡ Lawson, U. S. G. S., 15th Ann. Rep., p. 420.

|| Hinde, Univ. of Cal. Dept. of Geol. Bulls., Vol. I, p. 235; Smith, W. D., Phil. Jr. Sci., Vol. V., No. 5, p. 327 (1910).

** Hinde, App. I-9, Molengraaf's Borneo (1902); Martin, K., Reisen in den Molukken, Geol. Theil. Brill, Leiden 170 (1902).

†† Diller, J. S., Bull. Geol. Soc. Am., Vol. 19, p. 375.

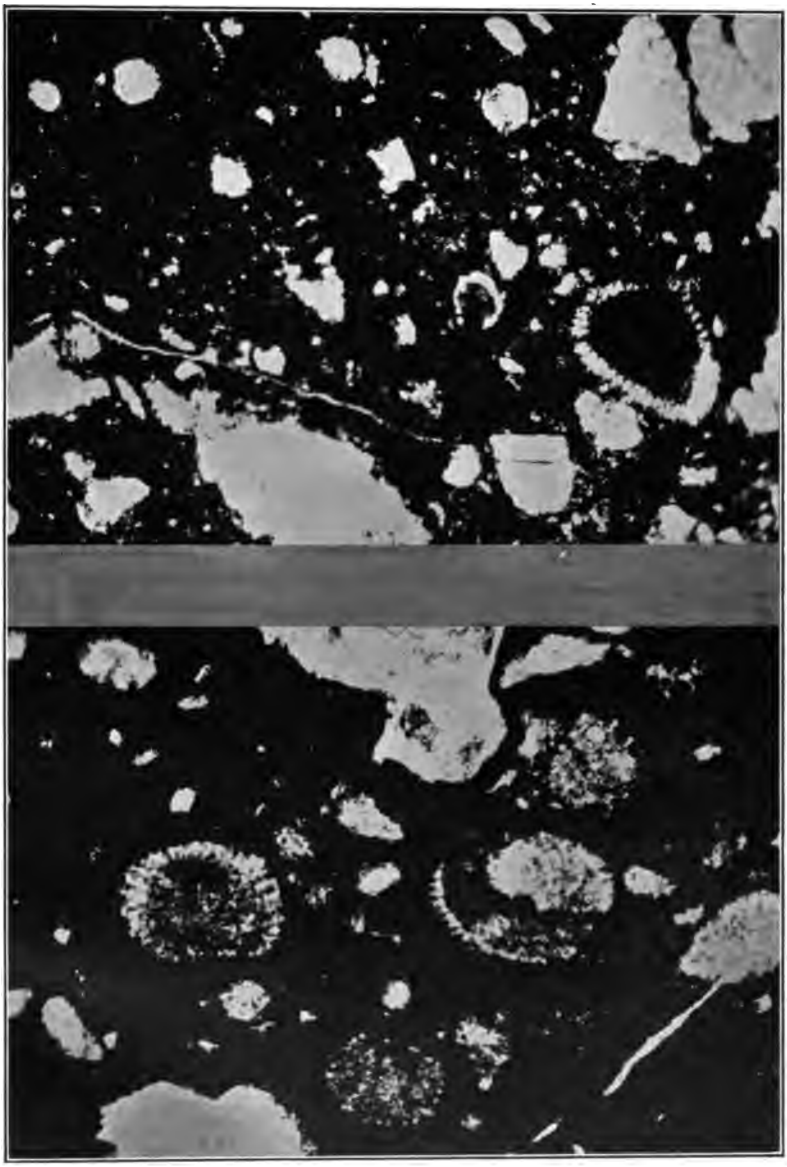

Plate I.—Radiolarian Cherts (Photomicrograph) (× 60)

We have seen nothing of these formations farther north in Oregon in the vicinity of the Cascades. This Jurassic flora is, indeed, a remarkable one. Many semitropical plants and trees once grew in this part of the world, but have since vanished from North America. One of these is the well known (in Japan) Gingko, with its odd, bifurcated leaf. The writer knows of only one specimen now growing in Oregon; it was imported from Japan, and is now flourishing on the campus of the State University at Eugene.

THE METAMORPHICS

The metamorphics include all of those rocks which have undergone a change of form due to dynamic causes. These may originally have been either sedimentary or igneous. Those which have come particularly within our range of study in the field, are serpentine and hornblende schist. These are seen to the best advantage, and most easily, perhaps, on the wagon road below Peel, on the south fork of the Umpqua. These localities have also been described by Diller.* At this place there is a confused mass of "metagabbro" (it looked more like diorite and metadiorite to the writer), which seems to have caused, by its intrusion, the alteration of the rocks surrounding it. What these were originally, we may never be able to say, for now there is a hopeless intermingling of serpentine and schist. The serpentine is, in places, of a clear, greenish, yellow color, while the schist is bluish green, due, no doubt, to the blue amphibole, glaucophane. The whole mass has been very greatly subjected to dynamic movements. What lies below this mass we can not say, and whatever overlay these rocks has been removed by erosion.

Some of this serpentine has a jade-like appearance, and, but for its tendency to crumble, might be of some value as an ornament. The clearest pieces, however, occur in thin streaks in the darker colored and more coarse-grained portion of the mass. There is, besides this clear serpentine, a considerable amount of epidote visible in the rock at this place. This is a common occurrence in some volcanic and igneous rocks.

Similar patches of serpentine in California, according to J. P. Smith, have originated from the alteration of peridotite dikes. In the Philippines it can be traced to a pyroxenite. In the last-named region, serpentine is found not far from radiolarian cherts.

Schists, but as far as we now know, lacking in the blue (glaucophane) variety, are common in the Philippines, associated with the radiolarian cherts, particularly in Ilocos Norte province, northwestern Luzon. We shall here quote a few paragraphs from an early paper by the writer, giving some account of these schists on the far side of the Pacific.

> Schistose rocks are apparently scattered quite generally throughout the length of Luzon, as well as in the other islands of the group; naturally, they are confined to the mountainous portions, where there has been a considerable amount of dynamic movement. In Ilocos Norte we find them in a narrow, irregular belt, bordering the granite (f. n.) dike, which runs roughly, north and south, across the country.
>
> At Dalumet I found magnetite, talc, mica (several species), actinolite and chlorite schists, all in a very much disturbed and mixed condition, but in this region the mica and talc schists prevail; farther to the north, near Dungon-Dungon, magnetite schists are better developed, and there is also a very feeble

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* Diller, J. S., Roseburg Folio, U. S. G. S.

development of eclogite. I found, from my study of schists and eclogites from the Coast Range of California, that the metamorphism of sedimentary rocks usually produced gneisses and schists; whereas, the eclogites could, in some cases, at least, be traced back to an igneous antecedent. However, in the Ilocos Norte region I have not in mind a single instance where I could actually trace these transformations in the field. This much, and only this, we can be sure of at the present time. The mica and talc schists are found between the granite (f. n.) intrusive mass and the later sediments; the magnetitic schists and eclogites are more intimately associated in the field with the basal igneous mass, usually near its edges.

It is quite possible that some of these schists may be metamorphosed ancient sediments, though this is not very probable. The presumption is that they are of more recent origin. We, doubtless, have as much reason for placing them in the Archean as have some writers in the case of the crystalline schists of Formosa, but there is absolutely no paleontologic evidence in either case.

With these Philippine schists is also associated serpentine, in which good showings of asbestos have been found.

The age of these metamorphic rocks, on both sides of the Pacific, has always been debatable, especially in the Philippines and Japan. In California, the age of the serpentines has been pretty definitely settled as being post-Jurassic. Louderback has stated that the Oregon serpentines, more particularly those in southwestern Oregon, are altered olivine-rich, basic, igneous rocks, associated with the Dillard series, and, therefore, are pre-Myrtle or pre-Knoxville (lower Cretaceous).

It seems to have been a penchant of Japanese geologists of the older school, many of whom were trained in Berlin, to regard everything like schists, gneisses, granite, etc., as necessarily old. In the Philippines, at least, similar formations seem, from their field relations, to be nothing more than metamorphosed Mesozoic or even Cenozoic rocks. Similar amphibole and sericite schists in Chosen (Korea) have been assigned by Koto to the Mesozoic. He says: "In the present state of my knowledge I shall assign it (the phyllite series), provisionally, to a metamorphic Mesozoic, although it is not intended thereby to exclude the idea of its being of the Proterozoic (Algonkian) or even the Paleozoic formation."* This sentence, taken with one on another page, is a confession on the part of Koto that the older conception, with regard to the crystalline rocks, was largely in error, for he says: "Writers on Korean geology, including myself, have also fallen into this habit of regarding the granitoid series as the primitive."

Economic

Associated with these serpentines, on both sides of the Pacific, are chrome iron deposits. The present war has stimulated a vigorous production of this valuable mineral. Nickel and copper deposits are also associated with these serpentines. The nickel deposits at Riddle† are so well known that they will be merely mentioned.

It may be noted, in passing, that there are some limestone lenses, locally metamorphosed to marble, in places in the Roseburg district, but no further study of them has been published since Diller first mentioned them. The writer saw one of these outcrops. It is unlikely, in his opinion, that these would serve any economic purpose other than the furnishing of a supply of lime or raw cement material, and this is being done, at the present time, for a cement plant at Oswego, Oregon.

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* Koto, B., "Journeys Through Korea," Jr. Sci., College Imp. Univ., Tokyo, Vol. XXVI, Art. II, pp. 162, 163.

† Diller, J. S., "Mines of the Riddle Quadrangle," Bull. 340, U. S. G. S., 134-52 (1908).

CRETACEOUS

For the purpose of completeness, we must make some allusion to the Cretaceous, although we have not yet studied any rocks in the Oregon Cascades proper belonging to this period, nor did we find any such in the Philippine series. However, both in California and Japan, we do find these formations well developed, and there are rocks bordering the Cascades which have yielded Cretaceous fossils. No later formations, until we reach those of the Eocene, are known to dip beneath the Cascade lavas, but, since the upper Cretaceous has been found in the John Day valley, it is only logical to assume that if we go deep enough we will find some remnants of Cretaceous also beneath the Cascades of Oregon. F. M. Anderson has the following to say of the Oregon Cretaceous closest to our Cascade region:

> In Rogue River valley beds of upper Cretaceous age occur, following, generally, the western side of the valley, and resting upon the older metamorphic slates and crystalline rocks, with a fairly uniform dip toward the east. The strata consist, for the most part, of sandstones and conglomerates, with a subordinate amount of shales. The conglomerates predominate in the upper part of the section, while the shales are common at and near the bottom. These beds are apparently equivalent to those of the upper Cretaceous of the Sacramento valley, to which they will be compared in more detail in another section. Similar beds are found in northern California. In Douglas county, near Riddle, is a syncline of Cretaceous strata, folded between areas of older metamorphic and intrusive rocks. Lithologically, it is a repetition of the equivalent portion of the Shasta-Chico series at the south, consisting of shales, sandstones and conglomerates.

Further on Anderson * shows the remarkable similarity of faunas in the Cretaceous of the Island of Yeso, Japan, to that of Oregon. The faunas contain six forms of ammonites, two of Inoceramus, one of Cucculaea, and one Nucula, which were either identical or very similar.

The Myrtle Formation

There is, in the region just outside the limits of the Cascades proper, i. e., southwest of Roseburg and Riddle, extending clear to the coast, a considerable area of heterogeneous rocks, to which Diller gave the name Myrtle formation, and in it he apparently included various Cretaceous horizons. The lower part contains Aucella piochi and Aucella crassicollis. The horizons corresponding to the upper Cretaceous or Chico are not so well differentiated. Louderback † has made an especial study of this region and of these rocks, and has given a summary of them. He describes a great series of sandstones, shales, conglomerates, some radiolarian chert (in the lower part), limestone, and these rocks, both those belonging to the lower and upper divisions, were intruded by "greenstones," "ultrabasic rocks," dacites, andesite, etc. To the lower division Louderback restricts the name Dillard, and, for the upper, he uses Myrtle.

The presence of the radiolarian chert, taken with other characteristics, as pointed out by Louderback, indicate that the Dillard series is to be correlated with the Franciscan of California and is, therefore, presumably pre-Cretaceous.

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* Anderson, F. M., Cal. Acad. Sci. (3d series), Vol. II, No. 1, San Francisco, Cal. (1902), pp. 17, 18; Anderson. loc. cit., pp. 59, 60.

† Louderback, G. D., Jr. Geol., Vol. XIII, No. 6, p. 514.

THE YOUNGER SEDIMENTS

Lying above (stratigraphically and usually topographically) the older rocks already mentioned, and below the lavas proper, the following stratified rocks are found: Sandstones, shales, tuffaceous sandstones, tuffs, interbedded conglomerates, and some interbedded volcanic flows as well, which have been referred to the Eocene, Oligocene, and Miocene. Not enough detailed study of the faunas and floras inclosed in these sediments has been made to give them formational names in every case, nor to correlate them, more than tentatively, with similar deposits in neighboring regions. The vertical distance from the bottom of the series to the topmost layer of tuff, we can only conjecture, for the most part, but we think it safe to assert that it amounts to many thousands of feet in some places, while in others it is much less than one thousand. The actual total thickness of these beds we have no sure means of knowing, because we have not a complete section anywhere, so far as we have examined the country. About twelve thousand feet of sediments, representing the Umpqua (Eocene sandstone) alone, have been noted by Diller. These can be seen to best advantage, perhaps, along the Little river, at the big wagon bridge east of Roseburg. The dip of the beds at several of these points averages twenty degrees, the inclination being toward the east, and the sedimentaries can be followed to a point where they dip beneath the lavas.

Naturally, the first thing to look for in an investigation of this kind, is a basal conglomerate, and, in order that one may know whether or not a supposed basal conglomerate really is one, he must know whether the conglomerate he is dealing with lies next to and unconformable with the basement rock, or only at the bottom of a section. In the older usages, it was not uncommon to use this word very loosely. For instance, there is a "basal conglomerate" reported as existing at a point on the Columbia river, near Warrendale, near the bottom of the cliff and below the railroad track. While this is basal, in the sense that it is the lowest member of the series exposed at this point, it does not mark an unconformity, nor is there probably a basal mass below it. It is, then, improper so to use this term.

On the Mohawk river, a tributary of the Willamette, at the first bridge beyond the first fork in the road above the town of Mabel, a conglomeratic mass was found. It lies close to the water, with about eight feet of loose river gravel above it. The formation consists of waterworn, badly decomposed pebbles and small boulders, which, for the most part, are igneous. Some of these included fragments, however, show stratification, and are clearly sedimentary. The dip at this point is very slight and to the southeast. The material forming this deposit is much weathered and oxidized, and might, therefore, be old. Nevertheless, heavily bedded yellow tuff is found about one hundred yards upstream, and, judging from what we know about the position of the tuff in other localities, we are inclined to believe that this conglomerate is not basal, but is an interbedded deposit.

Search was made near the granodiorite on the McKenzie river for a basal conglomerate, but nothing was seen which we could say definitely was such, though detailed work in that region might reveal its presence.

Diller, of course, has described conglomerates which may be regarded as basal, at the bottom of the Umpqua series, and having boulders derived from the Myrtle formation, to the west and below, stratigraphically.

The only other locality visited by the writer which showed anything which might be considered as being basal, is in Cow Creek canyon, at Nichols, a flag station on the Southern Pacific railroad, Douglas county, Oregon. In this canyon the writer found (already well known) several hundred feet of heavily bedded conglomerate, having a moderate dip to the west. The older (Jurassic or Cretaceous [?]) sediments lie below in the creekbed, dipping at a high angle to the east. This conglomerate has already been described by Diller,* and is named the Umpqua (from exposures along that river), and is Eocene in age. This is a basal conglomerate, though it does not rest on the basement complex. It does, however, mark an unconformity between the Eocene and older formations. After all, the rocks of this locality are not strictly in the Cascades, though they might all be found beneath the Cascades, could we get at them.

It seems, then, that, from the evidence which is at hand from this side of the range, most of the basal conglomerate which may be present at the bottom of our younger sedimentary series, is still covered by later material, talus, or valley alluvium.

THE EOCENE

The Sandstones

At many points in the Willamette valley there are sandstone outcrops, but in each section so little is exposed that one can, with difficulty, estimate the thickness of the formation. Again, we must go farther south, along the Umpqua, for our starting point. According to Diller, the sandstones there are at least twelve thousand feet thick. We quote here from Diller concerning this formation:

> The Umpqua formation is composed of an extensive series of conglomerates, sandstones and shales, with traces here and there of calcareous, siliceous beds, which, although of small extent, on account of their exceptional character, are treated separately as the Wilbur formation. The Umpqua is by far the thickest formation in the Roseburg quadrangle, but on account of the lack of good exposures of certain members of the series, the whole could not be accurately measured. The best outcrops are along the Little river, where a continuous section of a portion of the series is well exposed. * * *
>
> The Umpqua formation occupies a much larger area than any other in the Roseburg quadrangle. The main body lies west and north of Roseburg, and extends northeast to near the limit of the quadrangle, where it disappears beneath the lava at the western foot of the Cascade range. It extends up Little river and appears in patches above Peel, on Cavitt creek, and about White rock. These separated patches are remnants of a once continuous sheet, that lapped to the southeast, far over upon the older rocks. Fossils have not been found in all of these isolated patches, but are abundant near the mouth of Cavitt creek. Westward and northward, the Umpqua formation stretches far beyond the Roseburg quadrangle, and plays an important role in the makeup of the whole country west of the Cascade range.

We can not pass by, at this point, a most valuable paper for correlation purposes, namely, the one by Dickerson † on the "Fauna of the Siphonalia Sutterensis Zone," in the Roseburg quadrangle. In this,

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* Diller J. S., Loc. Cit.

† Cal. Acad. Sci. Proc., Vol. N (4th series), 113-128, Dec. 1914, San Francisco.

Dickerson correlates, very definitely, a portion of the Umpqua with the Tejon of California. Of this fauna, and the Oregon locality, he says:

> At the Oregon locality, however, a great thickness of ten thousand feet of Tejon strata lies below the beds which yielded the fauna described in this paper. The writer's previous conclusions, from a study of the Siphonalia sutterensis fauna, were based upon state of evolution, identity of a few species whose ranges were limited to the uppermost beds in the Tejon, in the San Francisco bay region, and the absence of many species which were characteristic of the lower zones of the Tejon. The recognition of the Siphonalia sutterensis fauna in Oregon gives stratigraphic confirmation concerning the position of this fauna in the Eocene time scale of the Pacific coast, i. e., the Siphonalia sutterensis zone is the *youngest* Eocene thus far recognized on the Pacific coast.

Several other more or less local formations are described by Diller in this same region, such as the Wilbur tuff lentil, the Tyee sandstone (a massive member overlying the Umpqua formation), and the Oakland limestone lentils, the latter containing fossils which are "not typical Eocene forms, but are probably Oligocene." The present writer has not encountered this limestone anywhere north of this point, and, therefore, he is of the opinion that it is of minor importance in a broad discussion of Cascade stratigraphy. For economic reasons, we wish we could say otherwise. It is not improbable that deep borings or excavations, farther north, in Eocene areas, would reveal other patches of this, but it would be pure chance.

The writer collected some fossils from these Eocene sandstone outcrops mentioned by Diller. As no new species were found, and as several of these forms have already been figured by Diller and Dickerson, he will merely enumerate some of the index forms in passing:

Venericardia planicosta (several varieties);
Pitaria martini, Dickerson;
Tivela weaveri, Dickerson;
Siphonalia clarki, Dickerson;
Cerithiopsis oregonensis, Dickerson;
Amauropsis umpquaensis, Dickerson;
Ancilla californica, Cooper;
Natica hanniballi, Dickerson;
Turritella uvasana, Gab.

Perhaps the best localities at which to collect this fauna are, first, 200 yards below the bridge (near the schoolhouse) three miles below Peel postoffice, in the river bed, and, second, just about one-fourth mile below Mr. Bond's house on the Little river, above Peel. At the first-named place, the principal form is Cardita planicosta, perhaps the best-known fossil in western stratigraphy, and at the second, Turritella uvasana.

Before proceeding to a consideration of higher horizons of sandstone, let us see what other localities furnish us with data regarding the Eocene. On the map by Arnold and Hannibal,** considerable areas are marked out as being covered by Eocene rocks. One of these is the strip of country through which the McKenzie river runs. The writer made a reconnaissance of the McKenzie River valley, touching the river at frequent intervals all the way from Springfield to McKenzie bridge, well up into the lavas. No sediments whatever were seen along this

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** Arnold, Ralph & Hannibal, H. "The Marine Tertiary Stratigraphy of the North Pacific Coast of America." Proc. Am. Philos. Soc., Vol. LII, No. 212 (1913).

stream. It is possible that the basalt which is everywhere encountered may be of Eocene age. We are not in a position to make the positive assertion that this is not so, but we ask the question, upon what is this based? It is not improbable that this basalt is a part of the younger lava, which, on account of the greater fluidity, came down farther toward the valley in that region, and, therefore, may quite as well be young as old.

The basalt of the many buttes along the eastern margin of the Willamette valley are considered by some to be Eocene, because they are, as a rule, veneered by Oligocene or Miocene deposits. The writer would like to suggest here that some of these basalts may very well be intrusive, as is certainly the case near the State University at Eugene, and, hence, are younger than the inclosing beds, that is to say, Oligocene or Miocene—more probably the latter. On the Santiam river we find basalt, interbedded with, and also overlying, Miocene(?) beds, and farther south we find the section as given by Diller across the Roseburg quadrangle, which shows diabase sills in Eocene sediments. It is entirely possible that deep borings in the McKenzie valley would penetrate the basalt and strike Eocene sediments below, or, for that matter, even older beds, if the drilling were continued long enough. At present, however, no evidence is at hand testifying positively in regard to Eocene in the McKenzie valley.

In the old quarries, one and one-quarter miles northwest of Albany, there are more exposures of Eocene formations. In the westernmost of the two quarries (the newer one), both of which have been abandoned, there is a section of fifty feet of sandstone, and tuffaceous sandstone and fine conglomerate, the beds dipping at a slight angle toward the northeast (this could not be ascertained with any definiteness). At the bottom there are heavy beds of sandstone, apparently without fossils.

If it perhaps seems to the reader that in some of these localities we are getting away from the Cascades, it should be borne in mind that if we get too close to the lava, we find our beds obscured. There is no question but that beds outcropping at Albany eventually dip under the Cascade lava superstructure.

The fossils in the conglomeratic portion of the section are, for the most part, only casts, while those in the upper sandstone have the shell better preserved. About three-fourths of a mile farther north is another old quarry with the section showing soil, tuffaceous sandstone, grayish to yellow sandstone, and heavy sandstone beds. The dip here is about nine degrees in a northerly direction (perhaps a few degrees east of north). Very few fossils were seen in these beds, but numerous fragments of carbonized wood were found. The fossils at the first locality seem to come from an interbedded conglomerate at a higher level, and from a much-oxidized sandstone in thinner beds near the top. In this upper portion there are either concretions or impressions of roots of some indeterminable plant. The total vertical exposure of the face in this quarry is about thirty feet, with the exception of the heavy beds at the bottom. The various beds are from one to two feet in thickness.

Specimens numbered 24, 25 and 26 are all representative of the formation at this locality, and, therefore, we give here a short description of them from an examination with hand lens. No. 24 is a very fine-grained buff to blackish sandstone, fairly soft, and nonfossiliferous. No. 25 is a dirty brown to black, and very much mottled, due, presumably, to fragments of volcanic material. It seems to be decidedly tuffaceous and nonfossiliferous. No. 26 is a very rusty looking (ferruginous) grit, or fine conglomerate; the matrix is a very fine sandstone, and in some cases, perhaps of basaltic material. The whole rock, and especially the inclosed pebbles, are so badly decomposed that it is difficult to make any definite statement with regard to the exact nature of the material. This bed of interbedded conglomerate is fossiliferous.

No. 27 is, in part, conglomeratic, but for the most part, is a dark sandstone with minute white specks of mica(?). This upper layer is the most fossiliferous, and the genera and species given in the list below came from this layer. While many of the fossils retain something of the original shell (rather bleached and crumbly, to be sure,), many are merely casts, and indeterminable. According to Diller,* the formations in the vicinity of Albany are Eocene, and the assemblage of forms in the above list confirms this. Dr. Packard, who is quite familiar with California horizons, informs me that the fauna found here, as shown in the writer's collection, indicates the Tejon subdivision of the Eocene.

Fossils from the quarry, one and one-quarter miles northwest of Albany.**

Dentalum sp.
Natica sp.
Amauropsis sp.
Turritella buwaldana, Dickerson
Turritella planicosta, Conrad;
Cardium cooperi, Gabb
Leda, c. f., gabbi
Tellina horni, Gabb;
Spisula c. f., merriami
Meretrix stantoni (?), Dickerson;
Corbula sp.;
Lunatia horni, Gabb.

At Wilhoit springs, on the east side of the Willamette valley, the writer examined a coal deposit at a point about one-half mile east of the hotel. Below the coal is a coarse-grained, bluish-gray sandstone, in which no fossils were found. Above the coal, however, in the clay roof, a number of plant remains were found, belonging, almost entirely, to one species of hemlock.† Whether or not this is of Eocene age remains to be determined.

Near Brownsville (about four miles south), at Biron's quarry, at the edge of the Cascades, in the western foothills, a very light tuffaceous sandstone was examined, which contained casts of very small pelecypod forms, which resemble Eocene species.

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* Diller, J. S. Guidebook to the Western United States, Shasta route; U. S. G. S. Bull. 614 D, p. 36.

** Determined by E. L. Packard.

† Determined by A. R. Sweetser.

THE OLIGOCENE QUESTION

The sandstones and shales, which have long been called Miocene, we note, are now referred by Arnold and Hannibal, in part, at least, to the Oligocene. Dall,* also, seems to feel sure that a division in these beds, which have heretofore been grouped together, must be made. So far, a clear separation has not been made, and we are not yet sure as to just what we shall call Oligocene, in Oregon, and what Miocene. The writer ventures the opinion that correlation of our west coast with the east coast of the United States will not be productive of the best results, as he hopes to show in this paper our affinities are with the east coast of Asia, rather than with the Atlantic provinces of America. If we could correlate directly with Europe in this matter of the Oligocene, it would be still better.

For the present problem, we have altogether too little accurate data, either from the field or from the laboratory, to begin splitting up the Tertiary into too fine subdivisions. If we should find localities in Oregon yielding abundant forms identical with those in the California Oligocene, then we would be justified, presumably, in referring the Oregon material to that horizon, as, in all likelihood, hydrographic conditions of the two regions might not have been essentially different, but here again we do not know definitely—we can only argue back from present conditions. That such was probably the case, I am led to think from information supplied by my colleague, Dr. E. L. Packard, who has made studies of the living faunas in both the San Francisco and Puget sound regions.

The most definite correlation the writer has been able to secure with reference to this, is that supplied by Dr. B. L. Clark of the University of California, who has kindly furnished the following list of forms from the sandstone, formerly referred to the Miocene, in Smith's quarry at Eugene:

†Amiantis mathewsonii, Gabb;
Chione mathewsonii, Gabb;
Sanguinolaria N. Sp.;
Panope astrellana, Conrad;
Mesodesma Sp. (?);
†Spisula ramonensis, Packard;
Spisula N. Sp.;
†Solen N. Sp.;
†Thracia condoni, Dall;
Diplodonta N. Sp. (?);
†Tellina oregonensis, Conrad;
Agasoma gravidum;
Tellina eugenia;
†Natica N. Sp.;
Natica recluziana var., listed by Dall as inezana.

Some of these are also found in the collection made by the writer at the city reservoir, College Crest, Eugene. It seems pretty clear, then, that much that has been referred to the Miocene must be reclassified as Oligocene, if the California and Washington faunas are Oligocene.

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* Dall, Wm. H. The Miocene of Astoria and Coos Bay, Oregon. Prof. paper No. 59, U. S. G. S. (1909)

† Marked forms are common in the *Oligocence* of the region of Mt. Diablo, California, Washington, etc.

It will be noted that the genus Solen occurs in this list. Dr. Thomas Condon grouped quite a number of horizons, apparently, and called them "solen beds." According to Arnold's* table, these so-called "solen beds" ranged from San Lorenzo (Oligocene) to the Empire (Miocene). Of course, at the time Dr. Condon did his work, no great refinement and exactness was possible.

A typical exposure of a similar sandstone, which is probably equivalent to that of the Smith quarry, is found on Reservoir hill, Eugene (the excavation for a new city reservoir on College Crest in the southern part of the city of Eugene). This locality has, perhaps, yielded the most perfect specimens of invertebrate fossils from this horizon anywhere in the state. Unfortunately, the opportunity to collect from this locality will not soon return. The writer was there at the time of the excavating (1915), and, with the assistance of school children, secured an excellent series of very perfect specimens, part of which were placed in the Condon Geological museum at the State University. At the time a report for the press was issued by Prof. G. J. Mitchell and the writer, in the hope of counteracting foolish statements by ill-informed persons, and we repeat some of the report as then issued:

"The principal formations seen in our examination of the excavation for the new reservoir on College Crest are as follows:

"1. A soft, though fairly tough, tuff formation, formed by material blown out from some volcanic vent and later water-sorted.

"2. A much harder, blue sandstone, characterized by small, hard concretions about the size of large glass marbles, and containing many genera of 'clams,' which are listed below.

"3. Layers of finer material, a sort of shale. This is buff-colored, and contains harder concretions, which are more or less rounded, and shaped something like 'coal balls.' There are plenty of iron stains, particularly along cracks and weathered surfaces, but no sign of iron ore, as stated in earlier press reports, anywhere around the workings.

"The deposit is of general and scientific interest because of the varieties of formations shown in a small area, the abundance of well-preserved fossils, and the fact that much interesting light is thrown on the past history of this part of Oregon. In the Miocene (or Oligocene), this part of the valley was under the sea. There were also active volcanoes either close to the shore or beneath the sea. There was subsequent upheaval, with folding and hardening of the sands and muds, making sandstones and shales, respectively, and then followed the undetermined hundreds of thousands of years of erosion; how many years, no man knows, and all estimates are, and can be, only guesses; certainly long before the earliest recorded history, which would still be comparatively recent, geologically speaking. More than this, we can not say."

The following is a partial list of the forms found in the coarse bluish-gray sandstone:

Solen curtus, Dall;
Dentalium substriatum, Conr.;
Crepidula praerupta, Conr.;
Spisula ramonensis, Pack.;
Spisula albaria, Conr.;

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* Arnold & Hannibal, loc. cit., p. 604.

Mactra;
Saxidomus;
Callista;
Tivela;
Cytherea;
Caryatis(?);
Macoma milinana, Dall;
Dosinia merriami (?), Clark;
Natica;
Fusus hecoxi (?), Arnold.

While a thorough study of the fauna from here has not yet been made, it seems to the writer that this resembles, in part, at least, the Oligocene fauna of California, though the first three forms are typical Miocene species as listed by Dall.*

THE MIOCENE

Typical and unquestioned Miocene beds have been found bordering the Cascade region at but few localities within that area. The formations are of four types: igneous, marine, fresh water and pyroclastic, with the last two not clearly differentiated. The igneous formations are mainly basalt intrusions, laccoliths, dikes, sills, etc., found in most of the many buttes bordering the Willamette valley. The sedimentary formations include conglomerate, sandstone, tuffaceous sandstones, shales and tuffs.

Washburne ** mentions "marine rocks of the upper division of the Miocene at Twin buttes, Linn county, and through the hills southward to West Point hill, beyond which they continue along the base of the Coburg hills in Lane county. At all these localities the dip is 5° to 10° east."

As yet, the subdivisions of the Miocene have not been worked out in sufficient detail to warrant the use of formation names. Washburne and others have divided it into an upper and a lower division, the former being marked by coarse, and the latter by more fine-grained rocks. The upper division is also marked by more pyroclastic material, while the lower is distinctly marine. The age determinations of the Miocene rocks have been made mainly by Dall and Knowlton, the former in the case of the molluscan faunas, and the latter working on the plants.

Typical fossils of the lower division found by Washburne on Spencer creek, ten miles southwest of Eugene, are:

Venericardia castor, Dall;
Angulus oregonia, Dall;
Crassitellites Sp.(?);
Macoma Sp.;
Cardium Sp.;
Trochita inornata, Gabb;
Bittium (?) Sp.;
Pecten.

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* Dall, W. H. The Miocene of Astoria and Coos Bay, Oregon. U. S. G. S. Prof paper 59.

** Washburne, C. The Oil and Gas Prospects of Northwestern Oregon. Bull. 590, U. S. G. S. (1914).

Fossils representing the upper division of the Miocene were collected by Washburne from the bluffs along the Willamette river near Springfield, and the writer also secured a large collection from there. Many of the forms are, unfortunately, casts, but generally determinable. As Dall has already determined most of these, his list, published by Washburne,** is given:

Hemimactra (spisula) albaria, Conrad;
Mulina cf. oregonensis, Dall;
Thyasira bisecta, Conrad;
Venus parapodema, Dall;
Marcia oregonensis, Conrad;
Cardium coosensis, Dall;*
Nucula (acila) conradi, Meek;
Yoldia condona, Dall;
Yoldia oregona, Shumard;
Leda cf. pygmea Fabricius;
Leda whitmani, Dall;
Phacoides acutilineatus, Conrad;
Diplodonta (felaniella) parilis, Conrad;
Tellina aragonia, Dall;*
Tellina eugenia, Dall;
Solen curtus, Conrad;
Thracia condona, Dall;
Thracia trapezoidea, Conrad;
Crepidula tingana, Dall;
Trochita inornata, Gabb;
Natica oregonensis, Conrad;
Neverita inezana, Conrad;
Thais af. decenicostata, Middendorf;
Pyrula modesta, Conrad;*
Fusinus oregonensis, Conrad;
Epitonium (arctoscala) condona, Dall;
Epitonium (catenoscala) oregonense, Dall.

One genus mentioned here, Crepidula, is very common in the upper sandy shale beds near Eugene. In some places, as in Westpoint hill, northeast of the town of Coburg, a zone of from one to two feet is made up of these curious little shells, very closely packed.

Arnold and Hannibal have referred the beds at Springfield already mentioned, to the Oligocene, but in this the writer is not yet ready to concur, though important stratigraphic points will be cleared by so doing. In his bulletin Washburne, who has studied Cascade stratigraphic problems much longer than some who have essayed to write on the subject, draws attention to an interesting point. He suggests the possibility of a fault along the east side of the Willamette valley in order to explain the seeming discrepancy in the sequence of certain beds on that side of the valley, and goes on to say, in a letter to the writer:

"The collection of Oligocene leaves made on the Vanduzen place, east of Coburg, and the presence of marine Miocene of the 'valley'

** Washburne, Oil and Gas Prospects in Northwestern Oregon, Bull. 590, p. 25, U. S. G. S. (1914).

* Species regarded by Arnold and Hannibal as characteristic of the empire formation (Miocene). Am. Philos. Soc. Proc., Vol. 52, p. 590, 1913.

type (or 'upper division') in the foothills, offer a convenient place to look for evidence for or against the fault hypothesis."

The crux of the matter lies in the Oligocene controversy, for in this section Washburne found shale with Oligocene leaves apparently above, stratigraphically, and certainly above, topographically, so-called marine Miocene. He goes on to say that if the Eugene sandstones and shales are Oligocene (according to Arnold and Hannibal), then no fault is necessary to explain the apparent discrepancy near Coburg. The writer was unable to find Washburne's precise locality, but he can say that he found no surficial evidence of faulting in that region, nor anywhere else along the Willamette margin. Accurate detailed folio work will be necessary to settle definitely some of these points.

Conglomerates

Interbedded with sandstones and tuffaceous sandstones of the Willamette valley, we occasionally find layers of conglomerate, varying from six inches to three feet or four feet thick. One of the best sections to show this is the railway cut in the high cliff at Jasper, on the Southern Pacific railroad (Natron cutoff), about eight miles southeast of Eugene, Oregon. This is undoubtedly a somewhat higher horizon than the others we have just been considering, for the Columbia lava comes in just above these beds, though not in this section. The following is, roughly, the series of beds exposed at this place (from the top downward):

	Thickness in feet.
Soil and broken rock above.	
Very coarse yellow material	8
Fine-grained yellow tuff, with streaks of whiter and finer ash with **plant impressions** [*]	10-15
Gritty and heavy beds of sandstone	10-20
Finer sandstone(?), apparently tuffaceous	15
Conglomerate (igneous pebbles)	2- 3
Sandstone or tuff (too high up on cliff to examine well)	12
Coarse conglomerate	4- 5
Fine shale	2
Heavy beds of buff-colored sandstone	20-25
Bottom beds of sandstone, hidden by talus, and close to the river	25-30

The age of the Jasper tuffaceous sandstones is evidently Miocene or younger, for, so far as we now know, most, if not all, of these less indurated beds containing plant impressions in the Cascade region are, according to Knowlton,[†] of Miocene or later age. Somewhat similar, but finer-grained material, lithologically, and, quite probably, stratigraphically lower, on the Goshen road, about one mile south of Springfield, Oregon, contains leaves and ferns, which Knowlton [†] has determined as belonging to the upper Eocene. Reference will be made to other plant horizons further on in this bulletin.

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[*] Specimens from this place were submitted to A. R. Sweetser, professor of botany in the University of Oregon. As much of the material is fragmentary, he was unable to identify them more accurately than to say that they represented species of either willow or poplar.

[†] Knowlton, F. H. Report on the Fossil Plants Associated with the Lavas of the Cascade Range. U. S. G. S. 20th Ann. Rept., Pt. III, p. 37 (1900).

No marine shells were seen in this section, and it is to be presumed that we are, at this point, above the horizon where they are generally found.

Topography

These sandstones and tuffaceous formations, on erosion, give rise to foothills with gentle slopes and rounded topography is the result. Many of the farms bordering the Willamette valley are located in this gently rolling sandstone country. When the soil of this formation has not had some additions, in the form of wash from surrounding volcanic rocks, it is rather poor.

Lithology and Structure

Now, as to the general appearance of these beds, we may find a few statements of assistance. The sandstone, where true sandstone, is usually heavily bedded, and is grayish to buff-colored in most exposures. Freshly broken surfaces, which are from deep enough below the weathered portion of the formation, are bluish-gray. The constituents of some of these sandstones, particularly the younger ones, are mainly the triturated fragments of volcanic rock (older basalts or andesites, for the most part), hence the predominating mineral fragments would be the darker minerals of these rocks. The lighter feldspars would be more apt to decompose, and so not remain to make up the resulting sandstone, and quartz is conspicuously absent; hence, the color of these formations is prevailingly dark, rather than light.

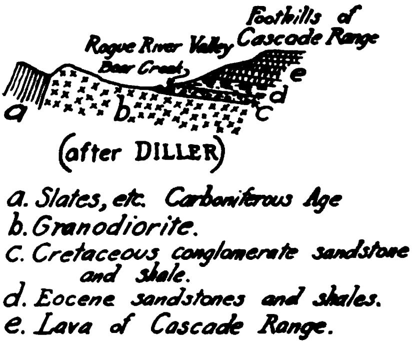
Foothills of Cascade Range
Rogue River Valley
Bear Creek
a
b
c
d
e
(after DILLER)
a. Slates, etc. Carboniferous Age
b. Granodiorite.
c. Cretaceous conglomerate sandstone and shale.
d. Eocene sandstones and shales.
e. Lava of Cascade Range.

Fig. 2.—Section in Rogue River Valley

Wherever the writer has encountered these younger, as well as the older formations, they have been found dipping toward the east or northeast (locally, in one or two places, nearly due north), that is, under the lavas of the main range. Attention is called to Fig. 2, which shows the general relationships in one portion of the range. This will be alluded to again. Usually the dip is not over twenty degrees, but on the Mohawk river, just above the town of Mabel, some beds were found (unfortunately it was not possible at that time to get very close to them, and so they were not carefully examined), which, at a distance of fifty yards, looked like sandstone. The dip of these beds was in an easterly direction, and at an angle of approximately forty-five degrees. It should be noted, that in considering these points, the writer is making no distinction, especially between the Eocene sandstones and the later ones. The younger beds are usually more yellowish in color, and have more tuffaceous material in their makeup. There may be a gentler dip to the younger beds, and hence, an angular unconformity between them and the older ones, but no detailed structural work has been done by the writer in this region; in fact, contact sections are rare in the Cascade portion of western Oregon.

A few remarks upon the comparison of these sandstones on this side of the water, with similar sandstones on the Asiatic side, may not be without interest. The sandstone inclosing the coal in the Philippines is a dirty, gray rock, almost identical with the Oregon sandstone of similar stratigraphic position. In both regions the igneous rocks, from which these sediments were derived, are predominantly basic. In neither region, in the vicinity of the coal, has the writer found any very distinctive fossils in this sandstone. In the Philippines, also, when we come to the upper series of tuffaceous sandstones, we find plant impressions, but, of course, with no similarities in the floras.

Economic Products

The possible valuable products, which come directly or indirectly from the older sandstone beds, are coal, building stone and grindstones. We might include in this list some of the mineral waters, as they issue from the sandstone at one place, at least, namely, Wilhoit springs, Clackamas county.

The Coal

A very fair seam of subbituminous coal, nearly four feet thick, has been prospected about one-half mile east of Wilhoit springs, in the western foohills of the Cascade range. Not enough development work has been done on it, as yet, to determine much about it. It is the writer's opinion, however, that this coal could be utilized to best advantage in gas producers, and more economically than the coal now shipped into the Willamette valley. We seriously doubt whether this coal could, for some time to come, compete with wood, as that is now being utilized in the state, but with the probable early exhaustion of California oil, Oregon coal will command attention.

At several other points in the Willamette valley coal has been located. Near Spencer's butte, about five miles south of Eugene, some thin, shaly beds of coal were found, and some development work done on them. This coal, however, is of exceedingly inferior grade.

At a place called Crabtree, not far from Scio, in Linn county, a farmer, in digging a well, struck coal which was reported to be eighteen inches thick, at a depth of ten feet.

At still another place, near Jordan, on the east side of the valley, coal was reported, but on examination it proved to be merely carbonized wood lodged in the tuff. The age of most of this coal is probably Eocene, though the writer suspects that some of it will, as in the Philippines, prove to be Miocene. Other coal localities, doubtless, are known on the east side of the Willamette, but no deposits comparable to the Coos county coal have been opened up.

Building Stone

At several places in the valley, in the western foothills, the sandstone from different horizons has been used as a building stone. One of the oldest quarries is the old Smith quarry, already referred to in connection with the Oligocene. This quarry has long since been abandoned. It is now used for two other purposes—first, as a poultry yard, and second, as a demonstration place for classes in geology at the State University.

There is another old quarry in an inferior sandstone at the entrance to Hendrick's park in Fairmount, Eugene. It is from this place that stone for the Eugene Central Presbyterian church was secured. The plain facts about this stone are that it is neither attractive nor durable, and, possibly, is actually unsafe, as the stone shows a marked tendency to sprawl and crack. The stone facing on this church is now having to be replaced, after having been up for a very few years.

There is another and more promising sandstone ledge at a point about one and one-half miles east of Saginaw, a small station near Cottage Grove, on the farm of A. F. Shireman. The heavy beds at this place dip in a northerly direction, at an angle of from five to seven degrees. These beds are alternating sandstones and tuffs, and seem to be much harder and better building stone than that at Engene. The writer saw one piece of stone that had been worked up as a headstone for a grave, and it made an attractive appearance. There appeared to be few shells and few cracks in the rock, and the quarry showed good "backs."

About four miles south of Brownsville, at the lower end of the Calapooia river, a quarry in tuffaceous sandstone has been opened up. The quarry is located in a sag between one of the long spurs of the Cascades and the outlying buttes. The formation has a gentle dip of ten degrees to the southeast. The beds vary in thickness from three to eight feet. The rock is a fairly fine-grained, very light (in weight) sandstone, which may be somewhat tuffaceous, but not to any great extent, as indicated by the abundant marine shells entombed therein. Near the surface the stone is buff-colored, but with depth it becomes whiter. This color is due simply to oxidation. The upper beds, at least, are quite fossiliferous in patches.

When dressed, this stone makes a very attractive appearance. The low specific gravity of the stone makes us doubt its ability to stand up under a considerable load.

The Shales

In the Cascade sequence of formation there are numerous beds of shale scattered throughout many horizons, some differing very markedly from others. There are those intercalated with the sandstones and tuffaceous sandstones of the Eocene, Oligocene and Miocene periods, indicating simply the existence at those places where they are found, of former quieter water and the deposition of finer sediments. Some of these may have been deposited in deep water and some nearer shore. Others, the older ones, are those associated with coal seams, and which grade into fire clay. These last are generally light-colored, and have a soapy feel. Some others are green, and still others, red. These may be volcanic muds, as their position just below the tuffs seem to indicate. These will be referred to under the pyroclastics.

Near the flag station called Williams, on the road from Albany to Detroit, there is an exposure of thirty to fifty feet of a light (in weight), white shale, which was examined for diatoms, but yielded none. The constituent grains are small, irregular particles of silica. There were included small, indeterminable fragments of leaves and twigs. Here the dip is about eight degrees to the eastward. These beds are evidently far above, stratigraphically, the exposures at Albany. No recognizable fossils were found in them. In fact, the writer has found few fossils in the shales proper. The presumption is that this formation is Miocene.

Economic

A fine diatomaceous earth occurs in the Deschutes valley, just east of the Cascades, and is being exploited. These diatomaceous deposits possess a particular interest, as, in California, the rich petroleum deposits seem to have some intimate relation to diatomaceous shales.

As certain shales are being used in the ceramic industry in Washington, just to the north of us, it is suggested in this connection that some industrially useful deposits might be opened up in Oregon in this class of deposits. Presumably the fire clays would be found suitable, also, for the more refractory kinds of products.

Limestone

Aside from the lenses in the Roseburg quadrangle, and the Oakland lentils, referred by Diller to the Cretaceous and Eocene periods, we know of no limestone in western Oregon north of the Gold Hill country, and this last is of Paleozoic age. Limestone has been reported from several places, among these being the Lucas ranch near Eugene, and the other, Markham, a short distance east of Mt. Angel. At the former place, according to G. J. Mitchell, who investigated the place in 1914 for the Bureau of Mines and Geology, there was some calcite in vugs in basalt. The writer visited the latter place during the summer of 1915, finding only sandstone, or coarse grit, full of shell fragments (principally pectens). The beds are probably Miocene in age. As the Portland Cement company had leased this with a view to using the limestone (?) in cement manufacture, he felt sure that this would be a genuine occurrence, but was disappointed. Pretty much the same might be said of the Dallas "limestone," on the west side of the valley. It seems that the conditions for limestone formation have not been favorable in Oregon since the beginning of the Tertiary, and the writer does not expect to find true limestone in, or bordering, the Willamette valley.

THE VOLCANICS OF THE CASCADES

Pyroclastics

We have gradually made our way up to the stratigraphic column till we have reached a series of formations which are, next to the lavas, the dominant type in the whole Cascade complement of rocks, namely, those which have resulted from terrific volcanic explosions and are known as pyroclastics (der. fragmental, and having their origin in fire). We have been wont to think more of the volcanic material of the Cascades either as pouring out of volcanic vents or quietly welling out of great fissures (all of which is correct), and have not, as a rule, thought much of what sort of cataclysms may have produced the many hundreds of feet of "fire-broken" rock. It is not meant to give the impression that these volcanic muds, tuffs, agglomerates, etc., and their origin, have not been noted before, for such is not the case. Many writers, including Diller, Condon, Russell and Collier, have called attention to the tuffs and agglomerates, particularly in their discussions of the geology of the eastern side of the range, where they are more prominent and more accessible for study. The layman, however, may not have given as much thought to them, or may not even have been aware that there were such deposits.

Volcanic Muds

Just below the tuffs and above the sandstones, there are beds of bluish or greenish shales, which, presumably, were once muds, and their association with the tuffs makes it probable that they represent volcanic muds such as are not uncommon in volcanic regions, and can be duplicated in the volcanic regions of the Philippine archipelago.

It is generally held, I believe, that many so-called red muds are peculiar to the deep sea, and certain theories have been built upon the basis of these to explain the permanence of ocean basins. The writer has not examined closely any of this deep sea red mud, but he ventures the opinion that if the ocean red ooze were indurated, it could not easily be distinguished from the volcanic mud found in many parts of the Asiatic volcanic region.

One of the best places to study these is on the Callapooia river, above Holly, in Linn county, where a deposit thirty feet or more thick can be seen. There is no bedding visible. The shale, on drying, "slacks" into rough cubes from one-quarter to one inch on an edge. Large boulders of andesite and basalt in the mass yield a clew to its origin. The color seems to be irregularly distributed throughout the exposure, and is doubtless due to the chemical state of the iron in the shale.

Some of this red mud has been used locally for paint, but it is a poor makeshift, as the iron content is low. These so-called "paint mines" are scattered promiscuously in the region of the volcanic rocks on the eastern side of the Willamette valley.

The Tuffs

To the writer, these tuffs are more interesting and more familiar than are the lavas, because they represent a phase of volcanic activity with which he is more familiar, and which is the dominant type on many islands fringing the coast of Asia. What terrific detonations there must have been in the countryside in those days; what clouds of volcanic dust, what lurid sunsets, what hurtling of bombs, what devastation! We can hear, almost, the cracking of giant trees as they are hurled to the ground! Were there people here in those dread days, they must have been hard pressed to find cover from the awful shower. Today, on the other side of the world, similar eruptions are taking place at longer and shorter intervals, and thousands of people have gone down before the remorseless blasts of gases that accompany these outbursts, and crops are ruined and laid waste. No longer ago than January, 1913, Taal volcano in the Philippine Islands, overwhelmed 1,335 people with ashes and gas, and crops were destroyed over great areas.

In Oregon, in those tempestuous days when the mountains were aborning, there may have been little sound, for the reason that there may have been no ears to hear it, and there may have been only the placid water of "Willamette Sound," or some other body of water, to catch the fall of fiery dust. We may never know. No fossils of primeval man have yet been found in this part of the world from this early time, and so we have only fragments of the trees and grasses that were beaten down and buried to help us conjecture as to what actually did happen. Some human bones were found in 1914, near Prospect, on the road from Medford to Crater lake, by a road gang which was changing the grade of the road. It is said that the bones were buried in the tuff, but those who found them did not appreciate the importance of noting the depth, position or characer of inclosing material, and so we have no reliable field data. The bones were sent to the University of California, to Dr. John C. Merriam, who has informed the writer that they are human bones, but that their scientific interest depends entirely upon the circumstances of their entombment. If these are the bones of a person who died at the time of the deposition of the tuff, we would then have a discovery of tremendous interest and of scientific importance. It is hoped that an opportunity to investigate the locality of the find may be found very soon, though the facts may no longer be obtainable.

As it is with the shales, so we find many varieties of tuffs from the coarse agglomerates * to the exceedingly fine-grained "ash," with little or no grit in it. We have selected four samples, from rather widely separated localities, to give the reader an idea, first, as to how widespread this material is in the Cascades, and second, to show the considerable variations in its physical characteristics.

(1) **Jasper, Oregon**—In the section already given on page 25, there is an exceedingly fine-grained, yellowish-white material, which has every earmark of an exceptionally finely triturated ash, which must have been carried high up into the air at the time of the eruptions of the period, and very probably carried by upper currents some distance, and, finally, deposited in water, where it was sorted still more by shore currents. This is the material which carries practically all the leaf impressions in the Jasper section. This material, if it did not fall in the water, was pretty close to shore.

(2) **Scotts Mills**—At Scotts Mills, about twelve miles east of Mt. Angel, and about forty miles southeast of Portland, there is a considerable deposit of very coarse tuff, grayish-yellow in color, in which large fragments of pumice can be seen. This rock is unlike that at most of the other localities so far visited, in that it is exceedingly tough, as evidenced by the fact that one can drive a ten-penny nail into a piece of it without cracking it, and the nail will remain fast, and can be bent back and forth without becoming loose. The rock can be sawed or cut with a knife very easily when fresh from the quarry, but it hardens on exposure. This stone, which is very similar to the

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* The writer prefers to use the word agglomerate, instead of conglomerate, so frequently wrongly employed in this connection. The word conglomerate should be restricted to that class of deposits in which the boulders have been rounded by water action, and which have a matrix of sedimentary material. In an agglomerate, the boulders are more or less angular, and they are inclosed in volcanic ejecta in a finer physical state.

Philippine tuff, locally known as "dhobie," was used to build the first building belonging to the German Catholic order which established Mt. Angel academy. Several tombstones in the private cemetery of the friars are made from it, and they seem to have endured well. This particular class of stone makes an excellent building stone for many special purposes, particularly in countries subject to earthquake shocks. Although we in Oregon may never require a stone with just this particular attribute, this stone could, and, it seems, should, find a ready market in Oregon. That it has not heretofore, would seem more on account of lack of information about it than through any deficiencies it may have. It is easily quarried, fairly accessible, tough, light, apparently quite strong, and hardens on exposure, rather than disintegrates, as is the case with most building stones.

(3) **Fossil Plants in the Tuff**—Near Warrendale, on the Columbia Highway, there is a great deal of tuff exposed, and it has different facies. Along the highway proper, the cliffs have some very coarse material, with the tree trunks standing upright. For descriptions of these excellent exposures along the Columbia Highway, the reader is referred to Williams' accounts.* Much of this material is fine-grained and nearly white, having the appearance of ash that had been blown from a great distance. In this last, the writer found some fairly good specimens of oak and poplar leaves. This locality (Moffat's creek), of course, has long been known. LeConte was the first to visit the locality, in 1871 and 1873, and Diller later collected fossil leaves which he submitted to Knowlton,† the veteran paleobotanist of the United States Survey, who gives a list of species determined from this locality. Apparently only two distinct forms at that time were found, namely, populus (poplar), zaddachi(?), Heer; and acer (maple), bendirei Lx. Knowlton called the whole assemblage of fossil leaves from the western base of the Cascades, of which these two are a part, Miocene. During the summer of 1916, Messrs. Bretz and Chaney of the University of Chicago, collected more specimens from this formation, known as the Eagle creek formation, on Eagle creek, and, as a result, determined twenty genera and forty species, including maple, oak, smilax, elm, magnolia, etc.

According to Williams, who evidently is basing his opinion upon the studies made by Messrs. Bretz and Chaney, this formation should be referred to the upper Miocene. This would, then, require the Columbia lava to be pushed up in the scale, and Williams has done this, suggesting the probability that the Columbia lava is Pliocene in age. This assumption at first looks to be justifiable, but, unfortunately, there are two good reasons why this can not be done. First, fossil leaves without fruit are often unsafe indices in stratigraphic work. The variation in modern leaves on the same tree is well known, and, furthermore, plants assumed a modern aspect earlier than vertebrate or invertebrate animals. The writer was of the same opinion as Williams when he began to investigate this problem.

The second and best evidence against this assumption is that to be seen in the region east of the Cascades in the classic John Day section. The section near Mascall's ranch, whose structure was so thoroughly described by Merriam, furnishes incontrovertible evidence, in the writer's opinion, that the Columbia lava is at least as old as the middle Miocene, perhaps, lower Miocene. In that section, which the writer has just visited and studied, the Columbia lava is found beneath the Mascall formation. Now the work of Merriam* and others has shown, conclusively, that the fauna of the Mascall is later Miocene. No one, the writer believes, will venture to assert that paleobotanical evidence is better than that furnished by the animal remains entombed in the Mascall.

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* Williams, Ira. Oregon Bur. Mines & Geol., Vol. 2, No. 3.

† 20th Ann. Rept. U. S. G. S., Pt. 3, p. 51.

It will be interesting to the reader, no doubt, to know what LeConte† had to say in 1874 about this formation at Moffat creek, and his interpretation of the facts:

> The order of events, as I conceive them, was briefly as follows: I. The region of the Columbia river was a forest, probably a valley, overgrown with conifers and oaks. The subsoil of this forest was a coarse boulder drift. 2. By excess of water, either by floods or changes of level, the trees were killed, their leaves shed and buried in mud, and their trunks rotted to stumps. 3. Tumultuous and rapid deposit of coarse drift, containing driftwood, covered up the forest ground and the still remaining stumps, one hundred, perhaps several hundred feet deep. 4. The surface thus formed was eroded into hills and dales. 5. Then followed the outburst of lava in successive flows, perhaps for a long period of time, and the silicification of the wood, and the cementation of the drift by the percolation of hot alkaline waters containing silica, as happens so commonly in sublava drifts 6. Finally, followed the process of erosion, by which the present stream channels, whether main or tributary, have been cut to their present enormous depths.
>
> In this last process of erosion, the main river progressed more rapidly than the tributaries, and these latter, therefore, ran into the river on either side by foaming cascades, until the river had cut down into the underlying conglomerate. Then they commenced to work back as perpendicular falls, until they reached their present position. The cascades of the Columbia river, as well as the perpendicular falls at the head of the deep side canyons of the tributaries, have all been formed, and their places determined, by the cutting of these streams through the harder basalt into the softer underlying conglomerate.

It seems, however, that the so-called "conglomerate," in which Le Conte found his fossil leaves at the base of the basalt, must be called a volcanic agglomerate. His idea was that this material was deposited during time of flood. It was clearly due to volcanic outbursts of ashes and bombs.

(4) **Volcanic Agglomerate**—Still another variety of tuff, in this case more properly a volcanic agglomerate, as the coarser varieties are called, can be seen at the river mill powerhouse on the Clackamas river. The material consists of huge andesitic and basaltic bombs, cemented in a coarse ash, making what is sometimes called a "volcanic breccia." This material is very interesting from an engineering standpoint, since it presented some serious difficulties when it came to locating a dam at that point. The difficulty was overcome by grouting this agglomerate with cement. A quotation from Mr. Rand's‡ (The Oregon engineer who had charge of the work) report:

> After a careful study of the conditions disclosed by the investigation, it was decided that in order to secure an impermeable foundation, it was necessary to practically provide for actually changing the structural character of the underlying formation. To do this, Mr. S. Howard Rippey, chief engineer for Messrs. Sellers and Rippey, engineers on the work, recommended that the most promising method would be the solidification of the porous material by the introduction of cement grout under pressure, but that the success of the work

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* Merriam, J. C. Bull. Dept. Geol., Univ. Cal., Vol. 2, p. 278 (1901).

† 20th Ann. Rept. U. S. G. S., Pt. 3, p. 51.

‡ Am. Soc. Civ. Eng. Trans., Vol. LXXVIII, p. 434 (1912).

> must be susceptible of demonstration by actual test before the superstructures should be started. Thorough inquiry failed to disclose any precedent for the use of grout for the general treatment of foundations, although it was found that cavities in limestone rock, under the new Croton dam, had been filled with grout, much as a dentist would fill a cavity in a tooth. The grouting method had also been used in filling back of lining walls in tunnels, etc. Notwithstanding the absence of precedent, it was decided to proceed with a grouting scheme, and a program was outlined for preventing leakage of water from the reservoir created by the dam, under or around the dam, to the low tail water level below the dam, and the experiments which should be made to properly demonstrate the efficacy of the method before the complete development should be undertaken, were prescribed. The general idea provided for drilling a double line of holes of an average depth of fifty feet under the heel of the dam, across the entire valley to, and under, the shore abutments, and the subsequent forcing into each of these holes of grout of such consistency as to percolate through the entire substructure.
>
> It was recognized that experiments would be necessary to determine the proper spacing of the grout holes, and their depth, which would insure sufficient diffusion of the grout through the varying material encountered, to create a continuous impermeable barrier to prevent seepage of water from the reservoir under the hydrostatic head which would be created by the dam. After drilling the double line of holes, the program contemplated the test of each hole with water pressure, a record being kept of the quantity escaping, and the pressure applied to each hole. Upon the completion of the tests, the cement grout was to be pumped into the holes under pressure, and after allowing time for hardening, a third line of holes was to be drilled midway between the first two, or outer lines, and tested with water pressure. The idea was that if water pressure applied to the center holes at, or slightly above, the hydrostatic pressure to which the rock would be subjected by the water in the reservoir after completion of the dam, and no appreciable leakage occurred, it would be reasonably certain that the cement grout had proven effective in making the entire foundation impermeable.

Of this formation Diller says:

> The rocks of the canyon walls are of four forms, volcanic breccias,* lava sheets, volcanic dikes and terrace gravels, the volcanic breccias being most abundant. The conditions that confront the engineer along the Clackamas river, in the volcanic breccia plain region, are very much the same as will be found all along the western foot of the Cascade range from the Columbia river in Oregon to the Feather river in California—one of the most important waterpower belts in the United States—and the successful solution of the problem it presents at one point will greatly facilitate the work elsewhere.

We can account for this great difference in the physical character of the tuff within this area, if we think of some of the material being carried higher and farther by the wind at one time than at another. A sort of selective process goes on in the air before the material ever falls into the water or upon the ground. The fact that numerous tree trunks, some standing upright and some prone, trunks of trees very like the same species now growing in these parts, indicates that all of this destructive outburst took place in the geological yesterday, but as to how many years, in exact numbers, we, perhaps, may never know.

The tuffs in Anna Creek canyon at Crater lake, though of much later age, might be referred to here. They are quite compact and are jointed like basalt, and the canyon walls through them are vertical in many places. The color of the material is buff to cream white. A great deal of it is exceedingly fine. The writer has seen almost identical ash thrown out in recent eruptions from Taal volcano in the Philippines. The presence of this tuff, together with the pumice scattered over great areas surrounding Crater lake, indicate, as Diller says,* a tremendous explosion or series of them at some time in the history of the region. Diller thinks, however, that Crater lake was not formed at the time of this explosion. The writer does think so, for the reason that he has seen one crater lake in the making in the Philippine islands. Then the whole process was one of explosion. However, since he has spent too short a time at Crater lake to enable him to speak with any conclusiveness, he will refrain, at this time, from any further statements, except to say that the present generally accepted explanation for the origin of Crater lake in Oregon by collapse does not satisfy him, and that he hopes to add something to the solution of this question at a future time.

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* The writer prefers the word agglomerate for this sort of deposit. Breccia might be derived from the Italian word, which means gravel, and, hence, has no connection with vulcanism, or from the French breche, meaning something broken.

Economic Utilization of the Tuff

McAlister, University of Oregon, has shown that good results may be obtained by mixing these tuffs with Portland cement.† Recent investigations in the Bureau of Science, Manila, on the utilization of volcanic tuff, has shown that this sort of material can be turned to commercial advantage in the making of sand-lime brick, and in connection with Portland cement, thereby reducing the amount of the latter necessary. Of course, pozzuolan cements have been known since the time of the Romans, but the utilization of them has been made more practicable by the investigations of the last half-dozen years. As Oregon has an unlimited supply of this material, there is no reason, unless it be that of a market, why some very effective construction material might not be made out of this deposit. In the region east of the Cascades, tuff is commonly used as a building stone, and in the Philippines it finds extensive use.

Topography

The topography of the tuff areas is not essentially different from that of the sandstone and shale areas. The two formations are sometimes difficultily differentiated, and the two kinds of material are often very intimately commingled. Furthermore, the tuff, in places, is found directly beneath the basalt, and protected by it, so that the basalt, and not the tuff, controls the topography. The tuff, being for the most part soft, and, in some cases, altogether unconsolidated, is easily eroded, and so we do not find, nor would we expect to find, sharp relief in this sort of formation. An exception to this is the tuff in Anna and other creeks, near Crater lake.

Since visiting the John Day valley, in eastern Oregon, the writer has been strongly of the opinion that these tŭffs occurring below the Columbia lava, in western Oregon, are to be correlated with the John Day series. In the absence of complete sections, and of vertebrate fossil finds, so far, in the Cascade tuffs, we, of course, can not be sure. Nevertheless, the position and the lithology in some places lead one strongly to suspect that there is something more than a fortuitous similarity between the volcanic ash deposits of the two regions. The material in the two regions might very well have been thrown out from the same vents within the Cascade region. The ash in the John Day series is generally finer than that in the Cascade region from the same horizon, but that is exactly what we would expect to find. The material blown to the greater distance would have to be finer than that deposited nearby. It is not unlikely that the red muds, referred to under the shales, typically exposed on the Calapooia river (western slope of the Cascades), are to be correlated with the Lower John Day, which looks remarkably like them. These red muds, too, occur about at the right horizon. In the absence of paleontologic evidence, we must leave the matter in this unsatisfactory conjectural state.

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* Geology of Crater Lake, Prof. Paper No. 3, U. S. G. S.; Phil. Journ. Sci. VIII, No. 5, p. 317.

† Univ. of Oregon Bull., New Series, Vol. X, No. 5, Jan. (1913).

THE LAVAS OF THE CASCADES

In opening this big subdivision of the subject, the writer wishes to state that while he has traversed the Columbia highway through the heart of the volcanics, has spent one week on and about the Three Sisters, and three days at Crater lake, he has made no intensive study of the lavas of this great range, and that he must, therefore, depend largely on what others have done to supply the details. The lavas of the Oregon Cascades may be, for convenience, divided into three general subgroups, namely, the older, younger and recent. As yet, the writer has seen no evidence to show that volcanoes were active in the Cascades during the Eocene, though activity is to be expected as early as that.

We have already, in discussing the Eocene, considered the subject of Eocene basalts, as indicated by Hannibal * in the McKenzie region. As for ourselves, we have seen no lavas, so far, in that region, which we could confidently place in the Eocene. This, of course, does not mean that there might not be such. In fact, in traversing any of the streams which cut across sediments in this region, one is apt to find sills of volcanic rock. Though these are generally of a later date than the inclosing rocks, they may still be fairly old, and, in the case of some of the buttes along the edge of the Willamette valley, the volcanic rock is perhaps as old as the Eocene, for we find Miocene sediments above some of them in such positions as to make it appear that the sediments were not necessarily pushed up by the volcanic rock. For instance, on the west side of the Springfield butte, there are shales and tuffaceous sandstones, Miocene or Oligocene in age, dipping toward, and also veneering the basalt, in such relations that we are led to believe that the basalt was there first, and that the sediments, after being laid down around the old flow or plug, were buckled up against this abutment; though this might be a dike cutting through a monocline, there is no visible contact. We know from Diller's work in the Roseburg quadrangle that diabase dikes (and perhaps sills) are found in Eocene, but presumably of later age than the inclosing beds.

Among the older volcanics, we might cite the andesites, the well-known "porphyry" of the prospector, of the Bohemia mining district, eastern Lane county. Much of the most recent lava of the Cascades is andesitic, but we believe that there is a much older and a later andesite, with basalt between them. Grouse mountain, Lane county, is made up pretty largely, in its upper portion, of andesite. It also usually constitutes the hanging wall of the gold-bearing veins of the district. Its exact relation to the rest of the stratigraphy, the writer has not yet

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* Arnold R. and Hannibal, H. Loc. cit.

had time to work out. Of this formation, McDonald has the following to say: *

> * * * The rocks of the district are andesitic lavas and tuffs of Tertiary age, which are cut by dacite porphyry, and probably by basalt. The andesites are the most abundant rocks. Seven consecutive flows, aggregating 500 feet in thickness, appear on the south base of Bohemia mountain. They vary from light to dark gray in color, and, in hand specimens, show small elongated phenocrysts of feldspar, and very small greenish crystals of pyroxenes or chlorite.

THE YOUNGER VOLCANICS

Overlying the tuffs, at almost any elevation from one hundred feet to twelve hundred feet above the sea, are to be found the younger volcanics. These younger lavas really comprise the most conspicuous part of the great Cascade structure, the conspicuous superstructure we may say, and, yet, not the top story, but that which has given the Cascades their striking character.

Basalt, or andesitic basalt, is the principal type of extrusive, the great Columbia basalt; but associated with these, we find, even at low elevations, rhyolite and dacite. As the mineral composition of basalts and andesites is almost the same, the chief difference being that basalt is a little more basic, and has olivine, we would naturally find it not always easy to draw a sharp line between the two, and that they are more or less intermingled. The exact relationships existing among these several kinds of flows has not yet, in every case, been investigated, and much remains in the way of detailed field work for the petrographer. At the places where contacts have been found by the writer, invariably basalt occurs just above the tuffs. About one and one-half miles below Cascadia (south fork of the Santiam), at an elevation of 1,200 feet, on the north side of the wagon road, about one hundred yards off the road, and just across the Santiam, the writer found the tuff (rather reddish and baked in appearance) with hard basalt above. The line of contact was as sharp and clear as in a diagram. As the tuff in this locality was first found by the writer at Foster, on Wylie creek (a tributary of the Santiam), at about 800 feet elevation, we can say that the tuff in this region is at least 400 feet thick.

Above the main pile of basalt, which we have generally believed to have issued from a series of great fissures, and to have welled out in a number of extensive flows, there are much later and less widespread flows from the ancient (but geologically very recent) volcanic vents of Hood, Jefferson, Three Fingered Jack, the Three Sisters, Diamond Peak, etc. The relation of the various flows to one another, and to a gravel formation called the Satsop formation, is well shown in the geologic cross-section, prepared by Williams,† of the Columbia gorge. In the lower part of this gorge we find the Columbia basalt; above this comes a variable thickness of conspicuous gravels, correlated by Bretz with his Satsop formation of Washington; above this, in turn, come thousands of feet more of andesitic lavas. Perhaps this sequence prevails throughout the range, but, bearing on that, we have too little data, at present, to allow us to dogmatize. Certainly there should be little question about this in the gorge section of the Columbia, where exposures are so plentiful and accessible.

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* MacDonald, U. S. G. S. Bull. 380, pp. 80-84 (1909).

† Williams, Loc. Cit. Map.

The Columbia Lava

This wonderful flow of lava, in extent, thickness and features, finds nothing comparable elsewhere in the world, save, perhaps, in the Deccan trap flows of India, in later geological history, or in the older volcanics of the Lake Superior region, in the earliest periods of the earth's turbulent history. Many of the early eminent geologists, such as LeConte* and Russell,† have written about this stupendous flow, and their descriptions are to be found both in technical and popular volumes.

The writer has seen this formation along one of the finest geological sections in North America, namely, the Columbia gorge, now followed by what is, perhaps, America's greatest scenic highway. At one point he counted twenty distinct flows of basalt, the whole pile aggregating over 2,000 feet. In some places these layers are horizontal; in others they show anticlinal and synclinal structures, as in the case of sedimentary beds. In places the lava stands up in the large columns, so characteristic of basalt in many parts of the world; in others it has the appearance of breccia which has not yet become cemented. A full description of the rocks in this gorge, with admirable photographs, will be found in the bulletin by Williams.‡ A still better locality in which to study the Columbia lava, particularly in its relation to other formations, is in the big basin of the John Day valley of eastern Oregon.

Topography

The basalts and associated lavas, being much harder rocks, naturally give rise to a different type of topography from that found in the foothills, where the softer sandstone, tuffs and shales are found at the surface. Gorges, cliffs and cascades (whence the name of the range) are the rule. There is one particular feature in the topography of the Cascades, as a whole, which has been noted by geologists, and, doubtless, by laymen as well, and that is the plateau-like appearance of the whole mass. Willis,‖ in his studies many years ago on the physiography of the Cascades in the state of Washington, dwelt upon the general uniformity of the skyline of the various ridges which go to make up the range. The Cascade range in Oregon is not one of mountain folds, properly speaking, though there is some anticlinal and synclinal structure to be seen in the basalt, and in the sediments beneath, but it is a dissected lava plateau. The streams and glaciers have been the dominant agencies in this work. Perhaps this is best brought home to the observer on the trip to Crater lake. Scarcely once does one see the summit, and only near the end does a glimpse of it come into view. Save for a slight upward grade, one might easily imagine oneself in low and fairly level country. Where the road follows the Rogue, or other fairly large river, however, the real ruggedness of the country is revealed.

The writer wishes here to dissent from the generally accepted idea that there has been extensive peneplanation in the Oregon Cascades. He thinks that the peneplain school of physiographers have overworked this term. He is, at the same time, well aware that there are many genuine instances of peneplains, and that in the Oregon Cascades local peneplanation is to be found, but thinks that the uniform skyline in many parts of the Oregon Cascade region can be explained in a simpler manner. If the preexisting topography were fairly level, the successive fissure flows would be more or less level on the surface, and when those became dissected through erosion, we would have left between the streams remnants whose tops would conform nearly to the original surface, and they would give a fairly uniform skyline. If the preexisting topography were not fairly even, then, the flows would not be horizontal. In eastern Oregon we find that the original country surface was fairly level where the lava flows are approximately horizontal, and quite rolling and rugged where not. The writer believes that many of the local anticlines and synclines in the Columbia lava are not due to folding, but due to the fact that the outpouring viscous lava followed the slopes of the preexisting topography, which seems, to the writer, at least in many places, to have been quite uneven.

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* LeConte, J. Am. Jr. Sci. & Arts III Series, Vol. VII, No. 39 (1874).

† Russell, I. C. Volcanoes of North America.

‡ Williams, I. Ore. Bur. Mines & Geology, Vol. 2, No. 3, (1916).

‖ Willis, B. Prof. Paper, 19 U. S. G. S. (1903).

Along with the increase in ruggedness of the high Cascade country, we find few human beings, more forest and wilder game. In this higher and more difficult country we find agriculture at a minimum, and other resources taking its place, such as mineral and forest products of various kinds, and still another, which is generally overlooked by many people, namely, scenery. But into these considerations we shall not enter now.

In the Philippines and in Japan, too, there are considerable Tertiary basaltic flows, but in these regions, at least, they are much less extensive and more broken up. It seems that the great fissures through which the Columbia lavas issued do not find their counterpart there, but that most of the material came from vents. It is true that these vents show an alignment along definite lines.

The Satsop Formation

A very important and conspicuous formation in certain localities is the gravel formation already mentioned, long known but restudied and named by Williams and Bretz, in the Columbia gorge section. According to Williams, the type locality in Oregon is along the Sandy river, near the Portland Auto club, and consists of "coarse quartzitic gravel, interbedded with streaks and heavy layers of sand, most of which has been so compacted, and the grains so cemented together, as to make the term 'sandstone' a proper one." Intercalated with this are beds of andesitic lava. "Besides the quartzite pebbles, there are various species of volcanic rocks, and the grains of sand are likewise mostly small scoriaceous slag or pumiceous pieces that have been brought directly from a close-by region of stirring volcanic activity." This deposit is considered by these geologists as of river and delta origin.

The age of the Satsop formation is discussed by Williams as follows:

> Yet above the basalt, and entering into the deformation of the Cascade range, is the ubiquitous Satsop. From its occurrence in the state of Washington, this formation has been correlated by J. H. Bretz * as the equivalent of sedimentary beds widely distributed along the Oregon coast, that were considered by J. S. Diller † in 1895 as belonging to the Pleistocene epoch of the Quartenary.

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* Unpublished manuscript. (Since published.—W. D. S.)

† 17th Ann. Rept. U. S. G. S., 1895, Part I.

In the absence of more definite data, we might accept such long-range correlation, and decide that the Satsop, as we have found it, is likewise Pleistocene. But, fortunately for our cause, and through the efforts and knowledge of an enterprising citizen of Portland, Mr. J. B. Winstanley, have these sedimentary strata, themselves been allured into the yielding up of their own secrets. Mr. Winstanley, several years ago, discovered a fossil bearing bed of compact, ashy shale, in immediate association with the gravelly members of this formation, in the bed of Buck (also called Trapper) creek, a tributary entering the Sandy river about four miles barely west of south from Crown Point, on the Columbia. Through the enthusiastic cooperation of this gentleman, and the assistance of R. W. Chaney, a representative collection of the plant remains from this locality was obtained. The fossil horizon is exposed three-fourths of a mile back from the Sandy river road, in the south side of the canyon of Buck creek, twenty-five feet above the water, beneath an overhanging cliff of conglomerate phase, in which pebbles of polished quartzite are common. Mr. Chaney states that in this one exposure of the Satsop, four general, and at least seven species, of plant life are represented. They include the oak, willow, walnut, and the sequoia. The latter is, apparently, the living redwood of California. Both the oak and the willow, likewise, closely resemble their living relatives in that sister state at the south.

There are, in this Satsop flora above the Columbia basalt, remains of several of the same genera found in the Eagle creek strata, below that great body of lava, but their specific characters are so markedly more modern as to brand this flora, at once, as belonging to a distinctly later age. On the other hand, this flora includes plants that at present grow upon the earth, most of them, however, flourishing only in the warmer climate of lower altitudes. Such equivalence to living forms might imply enforced migration, the retrieval of lost territory having not yet, to the present, been made; or, more likely, that the climate in which they grew, and prior to their displacement, was a more equable one than ours of today. In any case, similarity with land plants found elsewhere is undoubted Pleistocene strata, as well as with those of the present, affords us tentative grounds, at least, for saying, with added confidence, that the Satsop formation, as it enters into the structure of the Cascade range, appears to belong to the Pleistocene.

If this formation be fairly continuous throughout the range in this stratigraphic position, it makes a convenient dividing line between the Columbia basalt and the younger andesites of the higher parts of the Cascades.*

Characteristics of Recent Volcanics

According to Diller,† there are three types of lavas in Mount Mazama (the old volcano which once occupied the site of Crater lake, and whose upper portion, by explosion and engulfment, was destroyed) —andesites, dacites and basalts. The andesites of intermediate chemical composition were first, and the dominant type, of rock. This was followed by more basic lava, basalts, and, finally, by dacites. A new cycle started again with the eruptions from the very recent cone inside the lake, Wizard island, which ejected great blocks and bombs of andesite. The basalts all seem to have come from the minor cones situated on the slopes and at some distances from the original vent of the ancient Mount Mazama. One basalt flow, which poured out in Quarternary time, ran far down the Rogue valley.

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* Bretz, J. H. The Satsop formation in Oregon and Washington. Jour. Geol. (Chicago), Vol. XXV, No. 5 (1917).

† Diller, J. S. Prof. Paper III, U. S. G. S.

NOTE.—The interesting paper by Bretz,* wherein he presents a more complete statement of his ideas about the Satsop formation, came to hand after the body of the present paper was written. It seems to the writer, however, that gravels of widely different origins have been correlated without entire justification. Furthermore, what is the relation of the Satsop gravels to those formations in eastern Oregon, such as the Rattlesnake? There are quartzite pebbles in those. The Rattlesnake is, according to Merriam, Pliocene.

Patton † has made the most complete petrographic studies of the rocks in the high Cascades, and the reader is referred to his paper for detailed descriptions.

The writer has found andesite to be the dominant type of flow in the region of the Sisters, and Williams has found the same thing in other parts of the range. Williams has given the name Cascade formation to these upper andesitic lavas.

While there was much liquid lava, in the true sense of the word, among the recent volcanics of the Cascade range, the writer is of the opinion that much, if not the greater part, of the recent eruptive material was in the nature of large and small fragmental ejecta. This certainly seems to have been the case in the region of the Three Sisters, and to some extent around Crater lake. Furthermore, the shapes of the old eroded cones, all along the crest of the range, bear witness to the same fact, for we know that the shape of a volcanic mountain depends largely upon the nature of the ejecta. Liquid lava does not usually result in cone-shaped mountains. In this we see another parallel between the Asiatic region and the Cascades.

According to the investigations of the writer, checked by Iddings,* the Philippine volcanic rocks are largely pyroxene andesites, containing, in many instances, much hypersthene. These seem to be dominant. There are, besides, many active and dormant cones with basaltic material, and, in the last stages, characterized by basaltic andesites. With these are associated much agglomerate, tuff, etc. The last-named is extensively developed in the region around Manila, and is, perhaps, the best source of artesian water in the whole Philippine archipelago.

In Japan, according to Iddings, there are pyroxene andesites, andesitic basalts, and basalts with dacites, rhyolites, etc., with, however, some rather noteworthy differences from the Philippine and Oregon rocks. One of these is in the nature of the feldspar minerals in some of these extrusives. In the last named regions potash feldspar is notably deficient. This is significant.

The writer, who has now worked in field and laboratory on both sides of the Pacific, has been astonished at the remarkable similarity, in lithology, of collections of igneous rocks from the two regions. Not only are the hand specimens so much alike as to be easily confused, but mineralogically and chemically they are very close. In passing, we wish to point out that in the causes for the great variation, and the sequence in types of igneous rocks in the Oregon region, we have an interesting and fruitful topic for investigation, which is beyond the scope of the present paper. Work along this line has been begun in the laboratories of the department of geology of the university, but it is too early to record our findings.

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† Patton, Petrography of Crater Lake National Park, Prof. Paper No. 3, U. S. G. S.

* Igneous Rocks, Vol. II, p. 612 (1913).

A typical hypersthene-andesite shows:

	Crater Lake[*] *Per Cent*	*Philippines*[†] *Per Cent*
SiO_2	60.09	58.35
Al_2O_3	17.85	16.70
Fe_2O_3	2.03	4.08
FeO	3.45	3.28
MgO	3.50	3.29
CaO	6.28	7.71
Na_2O	4.17	2.62
K_2O	1.31	2.87

Recent Gravels

In addition to the gravels already mentioned, and those intercalated in the sandstones, shales and tuffs, and which are indurated to a greater or lesser degree, we must include in our series of sediments the many different beds of unconsolidated gravels of recent age. These are best seen, of course, along the river channels.

These gravels may be included in two subdivisions: (1) the **bench** gravels, and (2) the very recent deposits, which, for convenience, we may designate as the **valley bottom** gravels. Perhaps one of the best places on the west side of the Cascades to study the bench gravels is along the south fork of the Santiam river, where we have seen at least three good terraces, one above the other. These terraces lie at vertical distances above each other from twenty-five feet to one hundred fifty feet. These are, as any tyro in geology would know, merely the remnants of former flood plains, which have been incised by the stream as it lowered its bed. These terraces are quite generally wide enough and long enough to afford considerable acreage of flat and very arable land. It will be noticed by even the most casual observer who travels up any one of these main streams along the wagon road, that there is always a point upstream where the bench runs out, and he is compelled to ascend to the next higher bench or descend to the stream. This is characteristic of all normal flood plains. The material in the gravel beds is usually a well-assorted mass of andesitic and basaltic boulders, in which are intercalated layers of sand. The city of Portland is built, largely, upon bench gravel deposits, but these are, in part of delta and, in part, perhaps, of marine origin, and are of Pleistocene age.

In other places, the boulders in some of the gravel deposits have no definite arrangement, and then we are forced to look for the operation of other processes. The simplest, and, perhaps, the most natural explanation, is that many of these are merely talus deposits, and the second is that they are valley trains from the glaciers in the Cascades, which formerly had a much greater extension than at present. One of these deposits, of what is, perhaps, morainal material (at least it is very suggestive of this), can be seen at the town of Lowell, about twenty-five miles southeast of Eugene, Lane county, on the "Natron cutoff" of the Southern Pacific railroad, where the railroad goes through a huge cut about one-fourth mile east of the depot. The cut is filled with a hetrogeneous mass of angular boulders and huge blocks, mixed with small fragments, with no suggestion of any water sorting. Some of these boulders appear polished and faceted, and even striated, but these last may be only accidental. No polished or striated bedrock was anywhere seen, so the whole matter is inconclusive. If these are of glacial origin, they may mark one limit of glacial action in this region. It is possible, of course, that this is only valley train material. The locality is less than one thousand feet above sea level.

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[*] Diller, J. S. Geol. History of Crater Lake, U. S. G. S. Prof. Paper No. 3.

[†] Smith, W. D. Benguet Petrography, Phil. Jr. Sci., Vol. 2, No. 4.

Economic

These benches have two important economic aspects. In the first place, they are the sites of some of the best farm lands bordering the Willamette valley. After the boulders are cleared off the surface there is, generally, a fine soil on which to grow excellent crops, and the situation is admirable for farm sites. Second, these bench gravels have afforded, in the past, some of the most productive areas for placer mining and some of these may yet be found to offer a means of repeating Oregon's one-time great record in this branch of industry. Third, they afford sources of road material.

Potable Water in These Gravels

These gravels are also good water carriers, and furnish the farmers living on them with an abundance of cold, pure water. The best water the writer remembers to have drunk anywhere, in tramping about over these different formations, was that which came from the gravels of the Santiam flood plains.

Some search was made in these gravels to find remains of animal life that might have become entombed. The reason for this was two-fold—natural curiosity to find out if there might be any traces of primitive man in them, and second, and more particularly, to find marine shells, which might either prove or disprove the validity of Condon's theory of the Willamette Sound. No kitchen-middens nor marine shells of any kind were found, and of human remains, only one specimen has come to light, namely, a skull found on a sandbar of the Santiam river, which was probably washed out of some recent Indian burial ground which the river had cut into. This skull is of the "Flathead" tribe, as shown by the artificial deformation of the skull, and is, therefore, quite modern. The exact location of the burial ground is not now known. The skull was sent to the Condon museum by Mr. Wilkins of Lebanon, Oregon.

Glaciation in the Cascades

The subject of glaciation in the Cascades of Oregon is a large one, too large to be summarily dealt with here. Nevertheless, for the sake of completeness, we should make a few general statements. In the first place, glaciation in this part of the world was, and still is, local and alpine in type. Second, while the glaciers of a former period came well down toward the lowlands, probably never as far as the Willamette plain, they are now dwindled into very small proportions, and are relatively unimportant. They are interesting, but they are no longer great factors in sculpturing the land, as they were in the past. As one travels up the McKenzie, or other transverse valleys, he sees, first, deposits of glacial wash, valley trains of boulders, then remnants of moraines, **rôches moutonnées**, U-shaped valleys, etc.

Not only have the glaciers modified the topography of the Cascades by sculpturing them, but they have caused the transportation and deposition of materials which have benefited man in his various industries.

At one place, Hoover, upon the railroad which has its terminus on the upper Santiam, there is a very interesting deposit of very fine material, which is, evidently, a glacial rock flour, with not a trace of grit of any kind in it. This sort of material makes wonderfully productive soil.

About the sculpturing done by the glaciers, we may call attention to one other feature in passing. Many of the volcanic peaks now crowning the summit of the range are no longer conical in shape, but pyramidal, which may be explained by the cutting back of the glaciers radiating out from these high points on all sides.

The total number of glaciers in the Cascades of Oregon is probably not definitely known; certainly there are over a score, as Williams * has counted eleven in the vicinity of the Three Sisters. Collier glacier, between the north and south Sister, is perhaps the largest in the Oregon Cascades, and it is not three miles long, and is less than a mile in width.

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* Williams, I. Glaciers of the Three Sisters, Mazama, Vol. V, No. 1 (Dec., 1916).

As proof is being read a valuable contribution on the glaciers of Mount Jefferson, by Laura Hatch, published in the December, 1917, Mazama Magazine, is received.

GENERAL STRUCTURE OF THE CASCADES

As we have now sketched the salient points in the stratigraphy of this great range, we should discuss some of the more general features connected with this structure as a whole. It may be said that we have, almost without exception, found the dips of the sedimentaries on the western side of the range to be toward the east, and at moderate angles. Occasionally, a local north dip has been noted, but it must be purely local, and of minor consideration. Now, these easterly dips on the west side of the Cascades should be matched by westerly dips on the east side of the mountains, if the sediments continue to the east.

The writer has made some investigations east of the mountains, in the John Day valley, but not in the Deschutes. He has not seen any persistent western dips, nor can he find any reference to such in the literature. The Tertiary sediments of that region are largely covered by lava, and are quite different in origin from the marine formations on the western side of the range.

Diller* first called attention to these easterly dips, and he accounted for this state of things by an explanation which seems extremely likely and reasonable, namely, a sagging subsequent to the great piling up of thousands of feet of lava. In addition there probably existed, in the first place, a structural trough here, due to east and west folding of the underlying sediments.†

In this connection it may not be amiss to offer here a conjecture regarding the formation of the Willamette valley. If we presume that there was a broad syncline extending under the Cascade range, or a part of it, and it had its western edge on the west side of Willamette valley, and the center of this broad shallow trough were filled with tuffs and lavas, we could have a marginal valley, one side of which would be the sloping sides of the tilted sediments, and the other, or eastern side, would be the margin of the lava flows. Later, this valley would be filled up with gravel and silt, so that it would have a fairly even flat floor. The lateral planation of the meandering river would tend to widen and flatten it still more, and so, in the absence of positive proof to the contrary, we have an alternate theory to consider, along with the Sound theory of Condon.‡ As no terraces, wave-cut cliffs at all recognizable, traces of beaches, nor marine shells, later than the fossilized specimens of the earlier epochs have yet been found bordering this old sound, we may very properly consider a simpler suggestion. In this conception, which he arrived at independently, the writer finds himself in agreement with Arnold and Hannibal.**

As a matter of fact, we may have had both things happening, but the sound would be a mere episode in the entire story, and it may have been a fresh-water body, and not comparable to Puget Sound. Indeed, this is Mrs. Ellen Condon McCornack's conception of her father's theory. That there was much more water in this valley at a very recent date is attested by traditions and reports from the Indians, too numerous to ignore. In fact, the writer talked with a man not long ago, in the McKenzie valley, who said that his grandfather had been told by old Indians that their grandfathers had gone by canoe from the Coberg hills, across the Willamette valley, to the foothills of the Coast range. Such a condition, however, could be brought about by exceptional spring floods, and would not call for a permanent body of water. In the city of Eugene, on Sixth avenue, at a depth of a very few feet, old driftwood was found in river gravel and sand, which would show that the river has changed its course very materially, and that recently.*

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* 20th Ann. Rept. U. S. G. S. Notes on the Structure of the Cascade Range. Loc. cit. 599.

† This is also Washburne's idea, perhaps first elaborated by him in an unpublished manuscript.

‡ Condon, T., Oregon Geology, p. 134.

** Arnold R. and Hannibal, H., *loc cit.* —.

In all fairness, it must be stated that the opponents of the Sound theory have not yet satisfactorily explained the granite erratics found in Willamette valley.

The reader is again referred to the figure 1, where an attempt has been made to present, graphically, a very generalized scheme of the whole structure, as reconstructed from a study of the existing literature and field observations. This is to be taken as suggestive, rather than as representing the actual scale or condition of things, for the data is too meager at present to allow the writer to be sure of all the facts.

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* In 1861 the valley was again extensively flooded.

GEOLOGICAL HISTORY OF THE OREGON CASCADE REGION

Somewhere to the east of the site of the present Cascades, there must have been a considerable land area from which the early sediments could be derived. We do not know much about these early times or these early deposits in Oregon. In southern Oregon there are many square miles of Paleozoic sediments, which are still undifferentiated. Some of these may exist deeply buried beneath the Cascade lavas, and we know they occur in scattered localities to the east of the range.

Not until we reach the Triassic and Jurassic do we find a milepost to tell us how far we have come on our way. The radiolarian cherts of this period were of marine origin, but the manganese inclosed is not, necessarily, indicative of deep-sea conditions, as has been suggested by some. The writer has seen no manganese in the Oregon cherts, as in the case of the California radiolarian chert formation (Franciscan). And, even if it were present, it would not, necessarily, prove that it was of the same origin as the manganese nodules now found in the deep sea. The writer has seen manganese placer deposits in the Philippines, being formed simply by the concentration from the erosion of andesite, having innumerable veinlets of psilomelane throughout its mass. This was in the region of the cherts, but the manganese nodules were traced directly to the andesite, and none was seen in the cherts.

Following this period, there was a time of considerable igneous activity, during which these beds were intruded by dikes of peridotite, which altered, later, to serpentine. The hornblende schists, associated with the cherts and serpentine, undoubtedly represent altered shales of the same, or an earlier epoch.

At the end of the Jurassic came the Sierran disturbance, when the Cascades, as well as the Sierras, got their first big boost in the world. This was the period of the great granodiorite intrusions, with which many of our ore deposits are connected. We do not know exactly to what extent the sea encroached on the old land mass at the close of this great orogenic epoch, for in the vicinity of the Cascades we find only a few areas of Cretaceous rocks. However, at the western edge of the Cascades, at the old Forty-nine mines, two and one-half miles north of Ashland, Cretaceous conglomerates, sandstones and shales have been found resting on the older sediments and metamorphics. These dip easterly, and, presumably, run beneath the Cascades, as Cretaceous rocks are found again in eastern Oregon, near the John Day and Crooked rivers. In this period the climate was tropical or subtropical, and the faunal affinities were with the Japanese.

At the close of the Cretaceous there was another change in conditions, marked by erosion and deposition, followed by subsidence. Fairly warm conditions still prevailed, and vegetation grew rank in swampy areas. This inaugurated the period known as the Eocene. As J. P. Smith says:* "If a geologist in western America had first named the geologic systems, the Eocene would have received the name Carboniferous, for the most of the coal on the west coast belongs to that epoch." The Eocene in the Oregon Cascade region comprises thousands of feet of conglomerates, sandstones and shales. There may have been some outpouring of basalt during this time, as some assert, but the writer thinks that the basalts referred to this period are of later age. For a short time there was a connection between this Eocene sea via the Mississippi embayment and the Atlantic, but this was cut off in the succeeding epoch.

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* Smith, J. P. Loc. cit., p. 348.

Then followed a period of elevation and erosion, indicated by conglomerates. Beds containing a rich fauna of mollusks attest to the existence of marine conditions during the Oligocene epoch throughout a considerable length of California and Oregon. Meanwhile the climate was beginning to grow cooler.

The next group of rocks show deposits which were largely pyroclastic in origin, although intercalated with shales and conglomerates. The fossils contained are, for the most part, those of land plants, which were not greatly unlike those now living.

The Miocene was the period in which the Columbia lava was poured out, and it was one of the greatest epochs of volcanic activity in the world's history. Accompanying this outpouring of lava, and immediately following, there was considerable diastrophism. In fact, it is generally held that it was during this time that the Cascades attained much of their present elevation. The writer would like to suggest, in this connection, that the greater part of the height of the Cascade lava pile came, not from diastrophism, but simply from the piling up at the top of fresh lava and ejecta of one kind or another. An added height was gained during the Pleistocene by eruptions from vents like Hood, Adams, Jefferson, etc.

The Pliocene was probably a period of erosion, as no definitely known Pliocene deposits have been found in the Cascade region, unless some lava flows in the high Cascades are to be considered as having issued at that time. Since that time, or until comparatively recently, the history of the range has been that of a turbulent volcanic region, and in the southern part (Lassen peak), in California, it still is.

COMPARATIVE GEOLOGY

In closing, the writer wishes to call attention to some tentative conclusions, and to make some generalizations which he has arrived at from a personal contact with the geology of both sides of the great Pacific ocean.

In Table I are parallel columns giving, respectively, the stratigraphy (generalized) of parts of the Pacific coast of America, and that of the Philippines and Japan. The similarities between these regions are quickly seen by inspection of the table.

The salient events in California geological history have already been fully outlined by J. P. Smith.* The principal events in Japanese geologic history have been outlined by the Imperial Japanese Geological Survey.† The essentials in the Philippine geologic history have been traced by Becker‡ and the writer.‖

In examining all these records, we find much that is common to the four regions on both sides of the connecting ocean. J. P. Smith notes the connection between the later history of the Atlantic and Pacific regions. This is true, but is restricted to portions of the Quarternary, chiefly. In the earlier epochs, the affinities and likenesses point more to the other side of the ocean than to the opposite side of the continent.

If we consider diastrophic movements, climatic changes, as well as erosional and depositional features, we have still more remarkable coincidences between the two regions.

By resorting to the well-known horst theory, we can explain some of the major movements on both sides of the great ocean. As the great Pacific segment dropped down, it would act as a giant ram, which would force material up on either side, in fact, along the whole periphery, and this movement would either manifest itself through igneous material reaching the surface, or simply in elevation of the terrain, without any visible igneous action. Just how this would probably act has been explained by T. J. See§ and others. The mechanics of diastrophism and isostacy are beyond the scope of this paper.

At the first downward plunge of this ocean segment, it is presumable that there was manifested along the borders elevation only, to be followed later by the forcing upward of igneous material. This first upward movement of material might well be represented by diorite, which, on both sides of the ocean, appears to be the basement rock.

Until we get to the Triassic, we can not say a great deal, for the very good reason that we do not know much about the intervening periods. In the Triassic or Jurassic we see almost identical deposits laid down, and these associated with very similar metamorphic rocks, showing that similar deformational events were in progress in the two regions. The counterpart of the soda-bearing amphiboles, characteristic of the California and Oregon region, however, seems to be lacking in the Philippines, though they have been noted in Japan.

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* Smith, J. P. Salient Events in Geologic History of Calif. Science, new series, Vol. 30, pp. 346-350 (Sept., 1909).

† Imp. Japanese Geol. Survey, Tokyo (1902).

‡ Becker, G. F. Report on the Geology of the Philippine Islands; 21st Ann. Rept. U. S. G. S., Pt. III (1901).

‖ Smith, W. D. Essential Features of the Geology of the Philippine Islands. Phil. Jour. Sci., Vol. V, No. 5, Manila (1910).

§ Am. Phil. Soc. Proceed., Vol. 46, p. 369-415 (1907).

The striking resemblance of the marine invertebrate faunas, especially typified by the ammonites, in certain horizons of the Trias on both sides of the Pacific, was shown some years ago by J. P. Smith.[*] This resemblance is particularly striking in the lower Trias, and the Karnic and Noric horizons of the upper Trias. Also, according to Smith, there is a striking similarity in the marine faunas of Japan and western America, from the Pliocene on to the present time. The Cascade region, so far, has furnished little or no definite data regarding the Trias.

At the close of the Jurassic we have the great granodiorite intrusions on the American side, with granitic intrusions on the other side, to mark another sinking of the Pacific block, with corresponding creep of the plastic margins up into the weak border zone of the continents. On both sides of the ocean ore deposition occurred in connection with the granitic intrusions.

A great erosional interval followed next, on both sides of the Pacific; and in both Japan and California-Oregon regions, similar deposits, with similar faunas (subtropical), point to a closer connection than usual. Dr. Dickerson has informed the writer verbally that there are equivalents in Japan of the California, Martinez horizon of the Eocene.

In most of the regions bordering the ocean, the Eocene is really a Carboniferous period, with the coal inclosed in sandstones and shales of generally similar mineralogical composition and appearance. Typical analyses of coals from the Philippines, Japan and western Oregon, all of Tertiary (Eocene) age, are as follows:

ANALYSES OF COAL OF SAME AGE

	Philippines Batan Island	*Japan Kishima*	*Oregon-Coos Bay (Lillian-Diller)*
F. C.	44.86	42.60	41.47
V. C.	41.56	41.70	43.64
H_2O.	9.53	2.18	7.84
Ash	4.05	13.70	7.05
S.	2.37	2.60	.54
Sp. gr.	1.30	....	....
Calorific	6.983	7.788	....

The Oligocene in the Philippines was probably for the most part a limestone forming epoch but not so in Oregon.

The lower Miocene shows some general similarities between the Oregon Cascades and the Philippine region, and between northeastern Asia and the Pacific coast there was great resemblance in the matter of forests.

Asa Gray,[†] many years ago, in a classic paper, wrote as follows: "The case of the Pacific forest is remarkable and paradoxical. It is, as we know, the sole refuge of the most characteristic and widespread type of Miocene coniferæ, the sequoias. It is rich in coniferous types beyond any country, except Japan."

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[*] Am. Journ. Sci., 4th series, Vol. 17, pp. 217-233 (1904).

[†] Gray, Asa. Am. Jr. Sci. (3) CXVI 195 (1878).

Junghuhn, Koto and Becker * have all pointed out that a great gap, which may mean an unconformity, exists in the Malay Miocene, between the lower and upper divisions, and it is well known that a corresponding hiatus exists in the California region, between the Monterey and the San Pablo. This was followed by a great period of volcanic activity in all these regions, on both sides, and also by vein filling. This was one of the greatest epochs of ore deposition in the world's history, and rich gold, silver, with some tellurides and antimony, were deposited in California, Oregon, Philippines, Alaska, etc.

The Pliocene was, without much doubt, a time of land conditions with volcanic activity continuing. From this time on there is a great divergence in climatic conditions, for the Philippine region continued (and still continues) to be tropical, while Oregon and California suffered from glaciation (Pleistocene), in part. Japan is not known to have experienced any glaciation. The glaciers in the western United States were alpine, and not continental, which is in marked contrast to the Atlantic region. To correspond to the deposits of glacial wash on the American side, we have torrential wash in the Philippines, which simulate the former in a remarkable degree.

At the present time, we see at both the southern and northern ends of the Cascades, Lassen peak, California, and in Alaska, active volcanoes and, of course, many more active cones in the Philippines and Japan. Both the east coast of Asia (with its festoons of islands, Philippines, Formosa and Japan, etc.) and the west coast of America are a part of what is known among geologists as the "circle of fire," and both the products of the ancient and newer volcanoes are so alike on the two sides of the Pacific as often to defy even the specialist in distinguishing them.

Becker, in his early report on the Philippines, made during the insurrection in 1901, says: "The basalts and andesites of our Asiatic province might have come from Alaska, or from the western cordilleras of North America, so far as their composition and structure are concerned There is the same unexplained adherence of the feldspars to definite types, only emphasized by cases of exceptional composition. There is the same general uniformity in the ground mass of the rocks, accompanied by the occurrence of numerous exceptional microlites, and not very infrequent reversals of the ordinary rule of deposition, according to which the more calcic feldspars are precipitated before the more sodic species."

And inasmuch as the topography and geology of the two sides of the great ocean are so much alike, we might reasonably expect to find much in common between the peoples on both sides, for, when we get down to a study of fundamentals, we find that the dictum elaborated by a wise student of history, to the effect that the continents are the great barriers, and not the oceans, has considerable truth in it.

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* Becker, G. F. Rept. Geol. Phil. Isld., U. S. G. S., 21st Ann. Rept. (1901).

SUMMARY

1. The salient features of the stratigraphic succession in the Oregon Cascades, so far as known, have been reviewed.

2. A survey of the literature, and of the data gathered in recent field work, reveals the fact that not much is known with certainty about the formations and events prior to the Tertiary.

3. A second fact of importance, already known, has been emphasized, namely: That the later geological history of California and Oregon is very much the same. This might apply to the state of Washington as well, but the writer has purposely omitted a discussion of this, since he has never done any work there.

4. The third fact of importance is the remarkable coincidences of gealogical events on opposite sides of the Pacific, which can not be fortuitous. The three most striking instances of this are the period of Tertiary gold deposition, practically contemporaneous around the entire Pacific arc, the Eocene coal formations, and the tremendous eruptions of basaltic and andesitic lavas, which continue to this day, though not on so extensive a scale as in the past.

The general conclusion is that the geology of the various countries bordering on the Pacific must be deciphered and interpretated by duly considering the data from all these regions, and that, geologically (as in other ways), the Far East has much to contribute toward the solution of our western problems, and vice versa.

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Geology of the Oregon cascades

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